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RESPIRATORY CARE

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EDITORIALS

Ventilator Circuit Changes: "Wu Wei" May Save Time, Labor, and Money

ORIGINAL CONTRIBUTIONS

Effects of Decreasing the Frequency of Ventilator Circuit Changes on Rate of Ventilator-Associated Pneumonia in a Beijing Hospital

Frequency of Unsafe F_{IO_2} Levels in Infants Receiving Supplemental Oxygen by Nasal Cannula

Utility of Measurements of Oxygen Cost of Breathing in Predicting Weaning Success

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Albuterol sulfate can have a significant cardiovascular effect, significant hypokalemia and the potential life-threatening paradoxical bronchospasm. Caution is advised in patients with convulsive disorders, hyperthyroidism, diabetes mellitus, narrow-angle glaucoma, prostatic hypertrophy or bladder-neck obstruction. Co-administration of DuoNeb Inhalation Solution and other sympathomimetic agents may increase the risk of adverse cardiovascular effects.

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BRIEF SUMMARY OF PRESCRIBING INFORMATION

INDICATIONS AND USAGE

DuoNeb is indicated for the treatment of bronchospasm associated with COPD in patients requiring more than one bronchodilator

CONTRAINDICATIONS

DuoNeb is contraindicated in patients with a history of hypersensitivity to any of its components, or to atropine and its derivatives.

WARNINGS

Paradoxical Bronchospasm: In the clinical study of DuoNeb, paradoxical bronchospasm was not observed. However, paradoxical bronchospasm has been observed with both inhaled ipratropium bromide and albuterol products and can be life-threatening. If this occurs, DuoNeb should be discontinued immediately and alternative therapy instituted.

Do Not Exceed Recommended Dose: Fatalities have been reported in association with excessive use of inhaled products containing sympathomimetic amines and with the home use of nebulizers.

Cardiovascular Effect: DuoNeb, like other beta adrenergic agonists, can produce a clinically significant cardiovascular effect in some patients as measured by pulse rate, blood pressure, and/or symptoms. Although such effects are uncommon for DuoNeb at recommended doses, if they occur, the drug may need to be discontinued. In addition, beta agonists have been reported to produce ECG changes, such as flattening of the T-wave, prolongation of the QTc interval, and ST segment depression. The clinical significance of these findings is unknown. Therefore, DuoNeb, like other sympathomimetic amines, should be used with caution in patients with cardiovascular disorders, especially coronary insufficiency, cardiac arrhythmias, and hypertension.

Immediate Hypersensitivity Reactions: Immediate hypersensitivity reactions to albuterol and/or ipratropium bromide may occur after the administration of DuoNeb as demonstrated by rare cases of urticaria, angioedema, rash, pruritus, oropharyngeal edema, bronchospasm, and anaphylaxis.

PRECAUTIONS

General

1. Effects Seen with Sympathomimetic Drugs: As with all products containing sympathomimetic amines, DuoNeb should be used with caution in patients with cardiovascular disorders, especially coronary insufficiency, cardiac arrhythmias, and hypertension, in patients with convulsive disorders, hyperthyroidism, or diabetes mellitus; and in patients who are unusually responsive to sympathomimetic amines. Large doses of intravenous albuterol have been reported to aggravate pre-existing diabetes mellitus and ketoacidosis. Additionally, β-agonists may cause a decrease in serum potassium in some patients, possibly through intracellular shunting. The decrease is usually transient, not requiring supplementation.

2. Effects Seen with Anticholinergic Drugs: Due to the presence of ipratropium bromide in DuoNeb, it should be used with caution in patients with narrow-angle glaucoma, prostatic hypertrophy, or bladder-neck obstruction.

3. Use in Hepatic or Renal Diseases: DuoNeb has not been studied in patients with hepatic or renal insufficiency. It should be used with caution in these patient populations.

Information for Patients

The action of DuoNeb should last up to 5 hours. DuoNeb should not be used more frequently than recommended. Patients should be instructed not to increase the dose or frequency of DuoNeb without consulting their healthcare provider. If symptoms worsen, patients should be instructed to seek medical consultation.

Patients must avoid exposing their eyes to this product as temporary papillary dilation, blurred vision, eye pain, or precipitation or worsening of narrow-angle glaucoma may occur, and therefore proper nebulizer technique should be assured, particularly if a mask is used.

If a patient becomes pregnant or begins nursing while on DuoNeb, they should contact their healthcare provider about use of DuoNeb.

See the illustrated Patient's Instruction for Use in the product package insert.

Drug Interactions

Anticholinergic agents: Although ipratropium bromide is minimally absorbed into the systemic circulation, there is some potential for an additive interaction with concomitantly used anticholinergic medications. Caution is, therefore, advised in the co-administration of DuoNeb with other drugs having anticholinergic properties.

β-adrenergic agents: Caution is advised in the co-administration of DuoNeb and other sympathomimetic agents due to the increased risk of adverse cardiovascular effects.

β-receptor blocking agents: These agents and albuterol sulfate inhibit the effect of each other. β-receptor blocking agents should be used with caution in patients with hyperreactive airways, and if used, relatively selective β_1 selective agents are recommended.

Diuretics: The electrocardiogram (ECG) changes and/or hypokalemia that may result from the administration of non-potassium sparing diuretics (such as loop or thiazide diuretics) can be acutely worsened by β-agonists, especially when the recommended dose of the β-agonist is exceeded. Although the clinical significance of these effects is not known, caution is advised in the co-administration of β-agonist-containing drugs, such as DuoNeb, with non-potassium sparing diuretics.

Monoamine oxidase inhibitors or tricyclic antidepressants: DuoNeb should be administered with extreme caution to patients being treated with monoamine oxidase inhibitors or tricyclic antidepressants, or within 2 weeks of discontinuation of such agents because the action of albuterol sulfate on the cardiovascular system may be potentiated.

Carcinogenesis, Mutagenesis, Impairment of Fertility

Albuterol Sulfate: In a 2-year study in Sprague-Dawley rats, albuterol sulfate caused a significant dose-related increase in the incidence of benign leiomyomas of the mesovarium at and above dietary doses of 2 mg/kg (approximately equal to the maximum recommended daily inhalation dose for adults on a mg/m² basis). In another study, this effect was blocked by the coadministration of propranolol, a non-selective beta-adrenergic antagonist.

In an 18-month study in CD-1 mice, albuterol sulfate showed no evidence of tumorigenicity at dietary doses up to 500 mg/kg (approximately 140 times the maximum recommended daily inhalation dose for adults on a mg/m² basis). In a 22-month study in Golden hamsters, albuterol sulfate showed no evidence of tumorigenicity at dietary doses up to 50 mg/kg (approximately 20 times the maximum recommended daily inhalation dose for adults on a mg/m² basis).

Albuterol sulfate was not mutagenic in the Ames test or a mutation test in yeast. Albuterol sulfate was not clastogenic in a human peripheral lymphocyte assay or in an AH1 strain mouse micronucleous assay.

Reproduction studies in rats demonstrated no evidence of impaired fertility at oral doses of albuterol sulfate up to 50 mg/kg (approximately 25 times the maximum recommended daily inhalation dose for adults on a mg/m² basis).

Ipratropium bromide: In 2-year studies in Sprague-Dawley rats and CD-1 mice, ipratropium bromide showed no evidence of tumorigenicity at oral doses up to 6 mg/kg (approximately 15 times and 8 times the maximum recommended daily inhalation dose for adults in rats and mice respectively, on a mg/m² basis).

Ipratropium bromide was not mutagenic in the Ames test and mouse dominant lethal test. Ipratropium bromide was not clastogenic in a mouse micronucleous assay.

A reproduction study in rats demonstrated decreased conception and increased resorptions when ipratropium bromide was administered orally at a dose of 90 mg/kg (approximately 240 times the maximum recommended daily inhalation dose for adults on a mg/m² basis). These effects were not seen with a dose of 50 mg/kg (approximately 140 times the maximum recommended daily inhalation dose for adults on a mg/m² basis).

Pregnancy

TERATOGENIC EFFECTS: Pregnancy Category C

Albuterol sulfate: *Pregnancy Category C*. Albuterol sulfate has been shown to be teratogenic in mice. A study in CD-1 mice given albuterol sulfate subcutaneously showed cleft palate formation in 5 of 111 (4.5%) fetuses at 0.25 mg/kg (less than the maximum recommended daily inhalation dose for adults on a mg/m² basis) and in 10 of 108 (9.3%) fetuses at 2.5 mg/kg (approximately equal to the maximum recommended daily inhalation dose for adults on a mg/m² basis). The drug did not induce cleft palate formation when administered subcutaneously at a dose of 0.025 mg/kg (less than the maximum recommended daily inhalation dose for adults on a mg/m² basis). Cleft palate formation also occurred in 22 of 72 (30.5%) fetuses from females treated subcutaneously with 2.5 mg/kg isoproterenol (positive control).

A reproduction study in Stride rabbits revealed cranioschisis in 7 of 19 (37%) fetuses when albuterol was administered orally at a dose of 50 mg/kg (approximately 55 times the maximum recommended daily inhalation dose for adults on a mg/m² basis).

A study in which pregnant rats were dosed with radiolabeled albuterol sulfate demonstrated that drug-related material is transferred from the maternal circulation to the fetus.

During worldwide marketing experience, various congenital anomalies, including cleft palate and limb defects, have been reported in the offspring of patients being treated with albuterol. Some of the mothers were taking multiple medications during their pregnancies. Because no consistent pattern of defects can be discerned, a relationship between albuterol use and congenital anomalies has not been established.

Ipratropium bromide: *Pregnancy Category B*. Reproduction studies in CD-1 mice, Sprague-Dawley rats and New Zealand rabbits demonstrated no evidence of teratogenicity at oral doses up to 10, 100, and 125 mg/kg, respectively (approximately 15, 270, and 680 times the maximum recommended daily inhalation dose for adults on a mg/m² basis). Reproduction studies in rats and rabbits demonstrated no evidence of teratogenicity at inhalation doses up to 1.5 and 1.8 mg/kg, respectively (approximately 4 and 10 times the maximum recommended daily inhalation dose for adults on a mg/m² basis). There are no adequate and well-controlled studies of the use of DuoNeb, albuterol sulfate, or ipratropium bromide in pregnant women. DuoNeb should be used during pregnancy only if the potential benefit justifies the potential risk to the fetus.

Labor and Delivery

Oral albuterol sulfate has been shown to delay preterm labor in some reports. Because of the potential of albuterol to interfere with uterine contractility, use of DuoNeb during labor should be restricted to those patients in whom the benefits clearly outweigh the risks.

Nursing Mothers

It is not known whether the components of DuoNeb are excreted in human milk. Although lipid-insoluble quaternary bases pass into breast milk, it is unlikely that ipratropium bromide would reach the infant to an important extent, especially when taken as a nebulized solution. Because of the potential for tumorigenicity shown for albuterol sulfate in some animals, a decision should be made whether to discontinue nursing or discontinue DuoNeb, taking into account the importance of the drug to the mother.

Pediatric Use

The safety and effectiveness of DuoNeb in patients below 18 years of age have not been established.

Geriatric Use

Of the total number of subjects in clinical studies of DuoNeb, 62 percent were 65 and over, while 19 percent were 75 and over. No overall differences in safety or effectiveness were observed between these subjects and younger subjects, and other reported clinical experience has not identified differences in responses between the elderly and younger patients, but greater sensitivity of some older individuals cannot be ruled out.

ADVERSE REACTIONS

Adverse reaction information concerning DuoNeb was derived from the 12-week controlled clinical trial.

ADVERSE EVENTS OCCURRING IN ≥ 1% OF ≥ 1 TREATMENT GROUP(S) AND WHERE THE COMBINATION TREATMENT SHOWED THE HIGHEST PERCENTAGE

Body System COSTART Term	Albuterol n (%)	Ipratropium n (%)	DuoNeb n (%)
NUMBER OF PATIENTS	761	754	765
N (%) Patients with AE	327 (43.0)	329 (43.6)	367 (48.0)
BODY AS A WHOLE			
Pain	8 (1.1)	4 (0.5)	10 (1.3)
Pain chest	11 (1.4)	14 (1.9)	20 (2.6)
DIGESTIVE			
Diarrhea	5 (0.7)	9 (1.2)	14 (1.8)
Dyspepsia	7 (0.9)	8 (1.1)	10 (1.3)
Nausea	7 (0.9)	6 (0.8)	11 (1.4)
MUSCULO-SKELETAL			
Cramps leg	8 (1.1)	6 (0.8)	11 (1.4)
RESPIRATORY			
Bronchitis	11 (1.4)	13 (1.7)	13 (1.7)
Lung Disease	36 (4.7)	34 (4.5)	49 (6.4)
Pharyngitis	27 (3.5)	27 (3.6)	34 (4.4)
Pneumonia	7 (0.9)	8 (1.1)	10 (1.3)
UROGENITAL			
Infection urinary tract	3 (0.4)	9 (1.2)	12 (1.6)

Additional adverse reactions reported in more than 1% of patients treated with DuoNeb included constipation and voice alterations.

In the clinical trial, there was a 0.3% incidence of possible allergic-type reactions, including skin rash, pruritus, and urticaria.

Additional information derived from the published literature on the use of albuterol sulfate and ipratropium bromide singly or in combination includes precipitation or worsening of narrow-angle glaucoma, acute eye pain, blurred vision, paradoxical bronchospasm, wheezing, exacerbation of COPD symptoms, drowsiness, aching, flushing, upper respiratory tract infection, palpitations, taste perversion, elevated heart rate, sinusitis, back pain and sore throat.

DOSAGE AND ADMINISTRATION

The recommended dose of DuoNeb is one 3 mL vial administered 4 times per day via nebulization with up to 2 additional 3 mL doses allowed per day, if needed. Safety and efficacy of additional doses or increased frequency of administration of DuoNeb beyond these guidelines has not been studied and the safety and efficacy of extra doses of albuterol sulfate or ipratropium bromide in addition to the recommended doses of DuoNeb have not been studied.

The use of DuoNeb can be continued as medically indicated to control recurring bouts of bronchospasm. If a previously effective regimen fails to provide the usual relief, medical advice should be sought immediately, as this is often a sign of worsening COPD, which would require reassessment of therapy.

A Pan-LC-Plus™ nebulizer (with face mask or mouthpiece) connected to a PRONEB™ compressor was used to deliver DuoNeb to each patient in one U.S. clinical study. The safety and efficacy of DuoNeb delivered by other nebulizers and compressors have not been established.

DuoNeb should be administered via jet nebulizer connected to an air compressor with an adequate air flow, equipped with a mouthpiece or suitable face mask.

HOW SUPPLIED

DuoNeb is supplied as a 3-mL sterile solution for nebulization in sterile low-density polyethylene unit-dose vials. Cards of five vials are placed into a foil pouch. Supplied in cartons as listed below:

NDC 49502-672-30	30 vials per carton
NDC 49502-672-60	60 vials per carton

Store between 2°C and 25°C (36°F and 77°F). Protect from light.

DEY, Napa, CA 94558

03-485-21(BRS) May 2001

1. Gross N, Tashkin D, Miller R, et al. Inhalation by nebulization of albuterol-ipratropium combination (Dey combination) is superior to either agent alone in the treatment of chronic obstructive pulmonary disease. *Respiration*. 1998;65:354-362.

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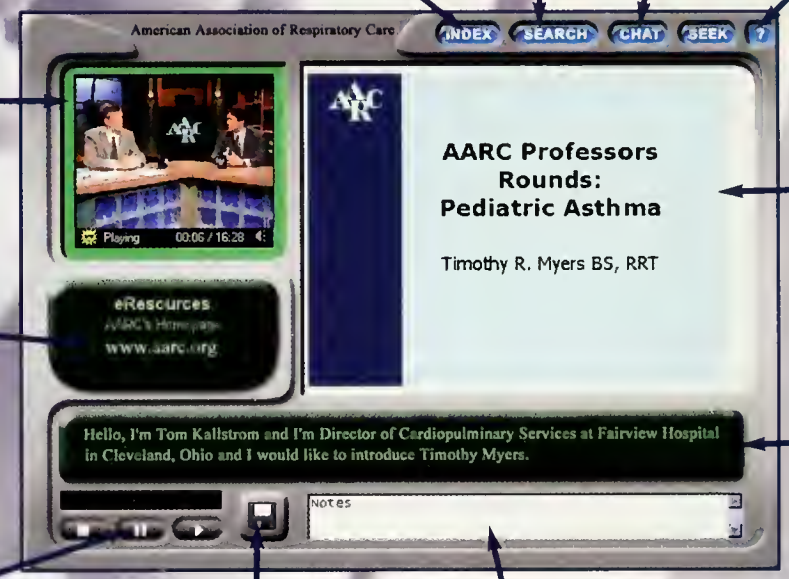

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CONTENTS

SEPTEMBER 2001 / VOLUME 46 / NUMBER 9

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EDITORIALS

Ventilator Circuit Changes: "Wu Wei" May Save Time, Labor, and Money 888
by Jean-Damien Ricard and Didier Dreyfuss—Colombes, France

ORIGINAL CONTRIBUTIONS

Effects of Decreasing the Frequency of Ventilator Circuit Changes to Every 7 Days on the Rate of Ventilator-Associated Pneumonia in a Beijing Hospital 891
by Jiang Na Han, Ya Ping Liu, Sui Ma, Yuan Jue Zhu, Si Hua Sui, Xiao Juan Chen, Dong Mei Luo—Beijing, China, and Alexander B Adams and John J Marini—St Paul, Minnesota

The Fraction of Inspired Oxygen in Infants Receiving Oxygen via Nasal Cannula Often Exceeds Safe Levels 897
by John W Kuluz, Gwenn E McLaughlin, Barry Gelman, G Patricia Cantwell, James Thomas, Thomas Mahon, Charles L Schleien—Miami, Florida

Utility of Measurements of Oxygen Cost of Breathing in Predicting Success or Failure in Trials of Reduced Mechanical Ventilatory Support 902
by Masahiro Mitsuoka, Katherine H Kimmnger, Katherine L Jacobson, F Wayne Johnson, David M Burns—San Diego, California

SPECIAL REVIEW SERIES

WHAT'S NEW IN THORACIC IMAGING?

ERIC J STERN MD,
SERIES EDITOR

Foreword: What's New in Thoracic Imaging? 911
by Eric J Stern—Seattle, Washington

Multidetector-Row Spiral Computed Tomography in the Diagnosis of Thoracic Diseases 912
by Samuel K Dawn, Michael B Gotway, and W Richard Webb—San Francisco, California

Magnetic Resonance Imaging of the Chest 922
by Charles S White—Baltimore, Maryland

Thoracic Sonography 932
by Christopher S Krejci, Erin J Trent, and Theodore Dubinsky—Seattle, Washington

Single-Photon Emission Tomography Imaging of the Chest 940
by David H Lewis, Brian Kott, and Arnold F Jacobson—Seattle, Washington

LETTERS

Weaning Parameters: Who Cares! 946
by Jack L DePriest—Johnstown, Pennsylvania
response by Neil R MacIntyre—Durham, North Carolina

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CONTENTS

CONTINUED .

ALSO IN THIS ISSUE

967 AARC Membership Application

858 Abstracts from Other Journals

976 Advertisers Index & Help Lines

976 Author Index

974 Calendar of Events

969 Manuscript Preparation Guide

965 MedWatch

973 New Products

975 Notices

BOOKS, FILMS, TAPES, & SOFTWARE

Chest Radiology Companion (Stern EJ, White CS) 948
reviewed by James R Patterson—Portland, Oregon

Imaging of Diffuse Lung Disease (Lynch DA, Newell JD Jr, Lee JS) 948
reviewed by Eric J Stern—Seattle, Washington

Case Review: Thoracic Imaging (Boiselle PM, McLoud TC) 949
reviewed by Julie E Takasugi—Seattle, Washington

Imaging of Diseases of the Chest, 3rd ed (Armstrong P, Wilson AG, Dee P, Hansell DM) 950
reviewed by Nisa Thoongsuwan—Seattle, Washington

Respiratory Care Equipment, 2nd ed (Branson RD, Hess DR, Chatburn RL, editors) 951
reviewed by Rex A Marley—Fort Collins, Colorado

Pharmacology for Health Professionals (Salerno E) 952
reviewed by Robert W Hirnle—Des Moines, Washington

AIDS Sourcebook, 2nd ed (Bellenir K, editor) 952
reviewed by Sharon K Martens—Seattle, Washington

Quick Reference to Critical Care (Diepenbrock NH) 953
reviewed by Sandra Sell—Pittsburgh, Pennsylvania

CONTINUING EDUCATION EXAMINATION

CRCE Through the Journal — 2001 955

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Research Pointers: Peak Expiratory Flow Sequence in Acute Exacerbation of Asthma—Birring SS, Heartin E, Williams TJ, Brightling CE, Pavord ID. BMJ 2001;322(7297):1281.

Deleterious Effects of Inhaled Beta-Agonists: Short-Acting and Long-Acting Agents Differ (editorial)—Sears MR. Chest 2001;119(5):1297–1299.

AIDS—The First 20 Years—Sepkowitz KA. N Engl J Med 2001;344(23):1764–1772.

AIDS and the Lung in a Changing World (editorial)—Mayaud C, Cadranel J. Thorax 2001; 56(6):423–426.

Pathophysiology, Clinical Manifestations, and Prevention of Ischemia–Reperfusion Injury—Collard CD, Gelman S. Anesthesiology 2001;94(6):1133–1138.

Optimizing Bronchodilator Therapy for COPD (editorial)—Lipworth BJ. Chest 2001;119(6): 1628–1630.

Analysis of Sputum in COPD (editorial)—Maestrelli P, Richeldi L, Moretti M, Fabbri LM. Thorax 2001;56(6):420–422.

Noninvasive Ventilation Routine Therapy for Community-Acquired Pneumonia? Not So Fast! (editorial)—Hill NS. Intensive Care Med 2001;27(5):797–799.

Extracorporeal Circulation for Acute Respiratory Failure—Mamprin F, Pesenti A, Fumagalli R. Intensive Care Med 2001;27(5):934–936.

Potentially Dangerous Negative Intrapleural Pressures Generated by Ordinary Pleural Drainage Systems—Bar-El Y, Ross A, Kablawi A, Egenburg S. Chest 2001 Feb;119(2):511-514.

OBJECTIVE: Clinical observation has identified cases in which the negative pressures exerted on patient chest drains have appeared to far exceed the level of suction intended. This study was designed to test whether the use of high rates of airflow in typical pleural/mediastinal drainage systems exerts excessively high negative pressures on the chest drainage tube. METHODS: Three pleural drainage systems were tested in vitro at negative pressure settings ranging, in 5-cm H_2O increments, from 5 to 35 cm H_2O. At each negative-pressure setting, each device was tested with three different rates of airflow. The negative pressures exerted in the chest drain were measured by water manometer and were compared with the initial pressure settings. RESULTS: When a high rate of airflow was used, all three systems produced negative pressures that exceeded the pressure level initially set; two of the systems exerted negative pressures that were approximately double those intended, for all pressure settings. CONCLUSIONS: Pleural drainage systems may exert excessive and potentially dangerous high negative pressures if high airflow is utilized. The risk to patients will be minimized if the airflow through the pressure-regulating chamber of the drainage system is adjusted to produce slow, consistent bubbling. High rates of bubbling and turbulence in the water column indicate that the negative pressure level may be excessively high, particularly for patients who do not have air leakage.

The Pulmonary and Systemic Distribution and Elimination of Perflubron from Adult Patients Treated with Partial Liquid Ventilation—Reickert C, Pranikoff T, Overbeck M, Kazerooni E, Massey K, Bartlett R, Hirschl R. Chest 2001 Feb;119(2):515-522.

OBJECTIVE: To assess the pulmonary and systemic distribution and elimination of perflubron ($C_8F_{17}Br_1$; LiquiVent; Alliance Pharmaceutical; San Diego, CA) during and following the period of partial liquid ventilation. DESIGN: Prospective phase I and II clinical trial. SETTING: Adult surgical ICU. PATIENTS: Eighteen adult patients (mean ± SEM age, 37.9 ± 3.4 years) with severe respiratory failure, some of whom required extracorporeal life support (72%), and who were managed with partial liquid ventilation with perflubron. INTERVENTIONS: Perflubron was administered into the trachea, and gas ventilation of the perfluorocarbon-filled lung (partial liquid ventilation) was then performed. Additional doses were administered daily for from 1 to 7 days, with a median cumulative dose of 31 mL/kg (range, 3 to 60 mL/kg). Measurements and main results: Patient blood samples were evaluated by gas chromatography for serum perflubron levels. Sequential lateral and anteroposterior radiographs were assessed, using a 5-point rating scale, for the degree of perflubron fill following the final dose. Samples of expired gas were collected, and the rate of loss of perflubron in the expired gas was measured by gas chromatography. Mean serum perflubron levels increased to 0.16 ± 0.05 mg/dL at 24 h following administration of the initial dose. A mean maximum level of 0.26 ± 0.05 mg/dL of perflubron was present in the serum 24 h following the administration of the last

dose. This level slowly trended downward to 0.18 ± 0.06 mg/dL over the ensuing 7 days ($p = 0.281$). Perflubron elimination via expired gas occurred at a mean rate of 9.4 ± 3.0 mL/h at 1 h, and 1.0 ± 0.4 mL/h at 48 h after the last dose ($p = 0.012$). By radiologic evaluation, perflubron was eliminated from the lungs progressively from 4.2 ± 0.2 at the time of administration of the last dose, to 2.8 ± 0.3 at 4 days later ($p < 0.001$). Perflubron tended to distribute and remain for longer periods in the dependent regions of the lung when compared to the nondependent regions (96-h perflubron fill score: posterior, 3.8 ± 0.5; anterior, 1.9 ± 0.4; $p = 0.004$). CONCLUSIONS: Perflubron is eliminated at a maximum rate of 9.4 ± 3.0 mL/h by evaporative loss from the airways and is retained in greater amounts in the dependent lung regions when compared to the nondependent lung regions. There is a low but measurable maximum blood concentration of 0.26 ± 0.05 mg/dL in patients after perflubron administration, which did not decrease significantly after cessation of partial liquid ventilation.

Filgrastim in Patients with Pneumonia and Severe Sepsis or Septic Shock—Wunderink R, Leeper K Jr, Schein R, Nelson S, DeBoisblanc B, Fotheringham N, Logan E. Chest 2001 Feb;119(2):523-529.

STUDY OBJECTIVES: Evaluate the safety of filgrastim (recombinant methionyl human granulocyte colony-stimulating factor) administration, combined with standard therapy, in patients with pneumonia and either septic shock or severe sepsis who were receiving mechanical ventilation. DESIGN: Multicenter, double-blind, randomized, placebo-controlled study. SETTING: ICU, multicenter. PATIENTS: Eighteen patients with pneumonia and hypotension, or in the absence of shock, two or more end-organ dysfunctions, were enrolled and treated. Baseline acute physiology and chronic health evaluation II scores and median age for the filgrastim ($n = 12$) and placebo ($n = 6$) groups were 25.0 and 49.5 years and 31.5 and 56.5 years, respectively. INTERVENTION: Filgrastim (300 microg) or placebo was administered I.V. daily for up to 5 days. Measurements and results: Study end points included safety; biological response, including endogenous cytokine levels, endotoxin levels, and neutrophil counts; and mortality. Cytokine and endotoxin levels were highly variable in both groups. By day 29, 3 of 12 filgrastim-treated patients and 4 of 6 placebo-treated patients had died. There were no differences in types and occurrences of adverse events, including ARDS, or in outcome between the two groups. Three of four placebo-treated patients had persistent bacterial growth on bronchoscopy repeated after 48 h compared with 2 of 10 filgrastim-treated patients. CONCLUSION: Filgrastim appeared to be well tolerated in this population of patients with pneumonia and severe sepsis or septic shock. Larger studies to determine the benefit of filgrastim in patients with pneumonia and sepsis or organ dysfunction are warranted.

A Study of Consecutive Autopsies in a Medical ICU: A Comparison of Clinical Cause of Death and Autopsy Diagnosis—Tai DY, El-Bilbeisi H, Tewari S, Mascha EJ, Wiedemann HP, Arroliga AC. Chest 2001 Feb;119(2):530-536.

OBJECTIVE: To determine the degree of concordance between clinical cause of death and autopsy diagnosis in a medical ICU (MICU) setting. DESIGN: Retrospective medical chart and autopsy report review. SETTING: MICU in a tertiary referral hospital. PATIENTS: Consecutive admissions to an MICU over a 2-year period from January 1, 1994, to December 31, 1995. INTERVENTIONS: None. Measurements and main results: One thousand eight hundred patients were admitted to the MICU during the study period. There were 401 in-ICU deaths (22.3%). The autopsy rate was 22.7% (91 of 401). The mean ± SD age of the autopsied patients (55.1 ± 13.5 years) was lower than those without autopsy (62.4 ± 15.2 years; $p < 0.001$). The two groups were otherwise similar with regard to sex, race, APACHE (acute physiology and chronic health evaluation) III scores, and lengths of stay in the MICU and hospital. The discordance between clinical and postmortem diagnoses was 19.8% (95% confidence interval, 12 to 29%). There were no differences in age, sex, APACHE III scores, predicted mortality, and lengths of stay in MICU hospital between patients with concordant and discordant diagnoses. In 44.4% (8 of 18) of the discordant cases, management would have been modified had the autopsied diagnosis been made premortem. Seven of the autopsied patients had organ transplantation. Three of the patients who had organ transplantation had discordant diagnoses, including two patients with disseminated fungal infection that was not diagnosed clinically. Although the observed discordance in transplant patients (43%) was higher than in those without transplant (19%), the difference was not statistically significant ($p = 0.15$). CONCLUSION: Younger patients tended to have a higher autopsy rate than older patients. The discordance between the clinical cause of death and postmortem diagnosis was 19.8%. In 44.4% of the discordant cases, knowledge of the correct diagnosis would have altered therapy.

Factors Associated with Prolonged Mechanical Ventilation Following Coronary Artery Bypass Surgery—Branca P, McGaw P, Light R. Chest 2001 Feb;119(2):537-546.

STUDY OBJECTIVES: To identify the typical duration of postoperative mechanical ventilation following coronary artery bypass graft surgery (CABG), and to identify risk factors for prolonged postoperative ventilation. DESIGN: Retrospective study of 4,863 consecutive patients using univariate and multivariate survival analysis to identify independent risk factors. SETTING: Saint Thomas Hospital, Nashville, TN, a 575-bed, academically affiliated, regional referral hospital specializing in cardiovascular diseases. PATIENTS: All patients undergoing CABG in our hospital from January 1, 1996, to December 31, 1997. INTERVENTIONS: None. Measurements and results: Duration of mechanical ventilation and mortality were measured. More than 94% of the patients were

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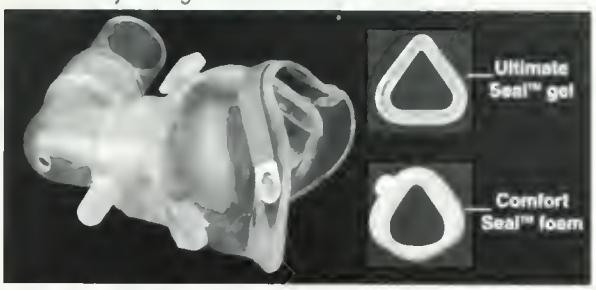

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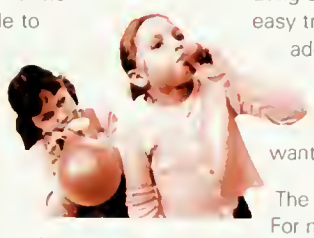

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Size and Composition Changes in Diaphragmatic Fibers in Rats Exposed to Chronic Hypercapnia—Kumagai M, Kondo T, Ohta Y, Ishihara T. Chest 2001 Feb;119(2):565-571.

OBJECTIVE: To test the hypothesis that chronic hypercapnia changes the composition of the respiratory muscle by continuous augmentation of ventilation. Materials and methods: Eighteen male Wistar rats were housed in 10% CO_2 in air for 19 weeks, and their minute ventilation V_E was measured every 6 weeks. The diaphragm, excited at 19 weeks of exposure, was classified as fiber type I, IIa, or IIb. Cross-sectional areas of individual fibers were measured. Fibers with a target-like appearance on reduced nicotinamide adenine dinucleotide-tetrazolium reductase (NADH-TR) stain also were counted. The data were compared with those of rats kept in room air. RESULTS: The mean (± SD) P_{aCO_2} after 19 weeks of sustained hypercapnia was 71.0 ± 4.7 mm Hg. The V_E remained at a high level until 12 weeks of exposure, and then it significantly decreased at week 18. In a comparison with the control rats, a larger number of type I fibers and a smaller number of type IIb fibers were found in the diaphragm of the chronically hypercapnic rats. In addition, the latter group's cross-sectional area revealed fibers of a significantly smaller diameter. Target-like fibers were observed in 5% of the NADH-TR-stained fibers in the chronically hypercapnic rats but were not seen in the control rats. CONCLUSION: By increasing the ratio of fatigue-resistant fibers, the diaphragm was able to adapt to a sustained load induced by hypercapnia. However, this adaptive process was accompanied by a degenerative change in the tissue.

The Value of a Hospitalist Service: Efficient Care for the Aging Population?—Hackner D, Tu G, Braunstein GD, Ault M, Weingarten S, Mohsenifar Z. Chest 2001 Feb;119(2):580-589.

BACKGROUND: We studied patients of a hospitalist teaching service and patients receiving routine private care (control subjects). We sought to evaluate whether inpatients cared for by an academic hospitalist service had lower lengths of stay and resource utilization rates. METHODS: Using monthly hospital census data, 477 hospitalist cases and 1,160 control cases were selected by explicit criteria from the Medicaid population of a large, university-affiliated, community medical center between July 1, 1996, and June 30, 1997. Outcomes in hospitalist faculty patients were compared to those of control patients under the care of private providers. RESULTS: Median length of stay was 4 days for control subjects and 3 days for the hospitalist service ($p < 0.0001$). Median total cost per case was $4,853 for control subjects and $4,002 for hospitalist patients ($p < 0.0001$). Only patients ≥ 65 years old showed statistically significant reductions in both length of stay ($p < 0.0001$) and total cost ($p = 0.002$). Subspecialty consultation rates were 37.6% for control subjects and 16.6% for hospitalist cases ($p < 0.0001$). We noted increasing consultations for patients ≥ 65 years old, especially in the control group ($p = 0.001$). No significant differences in mortality, 30-day readmissions, or interfacility transfers were observed. CONCLUSIONS: Patients cared for by an academic hospitalist service that includes actively participating medical residents appear to have lower lengths of stay, total costs, and consultation rates than patients receiving routine private care. The reductions are largely observed among patients ≥ 65 years old.

Management of Spontaneous Pneumothorax: An American College of Chest Physicians Delphi Consensus Statement—Baumann MH, Strange C, Heffner JE, Light R, Kirby TJ, Klein J, et al. Chest 2001 Feb;119(2):590-602.

OBJECTIVE: Provide explicit expert-based consensus recommendations for the management of adults with primary and secondary spontaneous pneumothoraces in an emergency department and inpatient hospital setting. The use of opinion was made explicit by employing a structured questionnaire, appropriateness scores, and consensus scores with a Delphi technique. The guideline was designed to be relevant to physicians who make management decisions for the care of patients with pneumothorax. OPTIONS: Decisions for observation, chest tube placement, surgical interventions, and radiographic imaging. OUTCOMES: Effectiveness of pneumothorax resolution, duration of and patient tolerance of care, and pneumothorax recurrence. EVIDENCE: Literature review from 1967 to January 1999 and Delphi questionnaire submitted in three iterations to a multidisciplinary physician panel. VALUES: The guideline development group determined by consensus the relevant outcomes to be considered in developing the Delphi questionnaire. Benefits, harms, and costs: The type and magnitude of benefits, harms, and costs expected for patients from guideline implementation. RECOMMENDATIONS: Management decisions vary between patients with primary or secondary pneumothoraces, with observation of small pneumothoraces being appropriate only for primary pneumothoraces. The level of consensus varies regarding the specific interventions indicated, but agreement exists for the general principles of care. VALIDATION: Recommendations were peer reviewed by physician experts and were reviewed by the American College of Chest Physicians (ACCP) Health and Science Policy Committee. IMPLEMENTATION: The guideline recommendations will be published in printed and electronic form with distribution of synopses for patients and health care providers. Contents of the guideline will be incorporated into continuing medical education programs. SPONSORS: The ACCP.

Home Ventilator Low-Pressure Alarms Fail to Detect Accidental Decannulation with Pediatric Tracheostomy Tubes—Kun SS, Nakamura CT, Ripka JF, Davidson Ward SL, Keens TG. Chest 2001 Feb; 119(2):562-564.

BACKGROUND: Positive-pressure ventilators are equipped with low-inspiratory-pressure alarms to protect patients from hypoventilation. Small uncuffed tracheostomy tubes have a high resistance, and may not trigger these alarms during decannulation. Study objective: To determine whether ventilator low-inspiratory-pressure alarms are effective in detecting tracheostomy decannulation. DESIGN: We connected tracheostomy tubes of varying inner diameters (3.0 to 6.0 mm) to a home ventilator and simulated decannulation using low (tidal volume [V_T], 600 mL; peak inspiratory pressure [PIP], 25 cm H_2O), medium (V_T, 800 mL; PIP, 30 cm H_2O), and high (V_T, 1,000 mL; PIP, 35 cm H_2O) ventilator settings. RESULTS: When the ventilator low-inspiratory-pressure alarm was set at 4 cm H_2O below the desired PIP, it failed to alarm for simulated decannulation of tracheostomy tubes < 4.5 mm on low and medium settings, and < 4.0 mm on high settings. When the ventilator low-inspiratory-pressure alarm was set at 10 cm H_2O below the desired PIP, it failed to alarm with tracheostomy tubes < 6.0 mm. CONCLUSION: We conclude that ventilator low-inspiratory-pressure alarms fail to alarm during simulated decannulation with small tracheostomy tubes commonly used in children. We speculate that low-inspiratory-pressure alarms set at 4 cm H_2O below the desired PIP will detect more decannulation than when set at 10 cm H_2O below the desired PIP.

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Allosteric Modification of Oxygen Delivery by Hemoglobin—Wahr JA, Gerber M, Ventz J, Baliga N. Anesth Analg 2001 Mar;92(3):615-620.

Hemoglobin affinity for oxygen is altered by pH, temperature, and high altitude, making oxygen more readily available to the tissues. RSR13 (Allos Therapeutics, Denver, CO), an analog of the drugs clofibrate and bezofibrate, causes a dose-dependent, rightward shift of the oxygen dissociation curve in animals and humans. We tested the safety, pharmacodynamic, and pharmacokinetics of RSR13, an allosteric modifier of hemoglobin, in patients having general surgery in a prospective, randomized, double-blinded, placebo-controlled, dose-escalation clinical trial. After the induction of general anesthesia with endotracheal intubation, 26 patients who consented were randomly assigned to receive an infusion of RSR13 or placebo (2:1) in an ascending dose scheme. Doses studied were 10, 20, 30, 40, 50, 60, 75, and 100 mg/kg infused for 30-60 minutes. Samples were taken for determination of RSR13 concentration in plasma, red blood cells, and urine, as well as for determination of the p50 in blood by using three-point tonometry at frequent intervals after the infusion of the study drug. The RSR13 administration resulted in a dose-dependent rightward shift of the oxygen dissociation curve, with the target p50 shift of 10 mm Hg achieved at the 75- and 100-mg/kg doses. No differences were seen between RSR13 and placebo groups in laboratory or hemodynamic findings, with the exception of a transient, limited increase in serum creatinine in 3 patients who received RSR13. These increases peaked at 48 h (2.2, 3.5, and 4.5 mg/dL respectively), were not associated with oliguria, did not require treatment, and did not prolong hospitalization in any patient. The reasons for the unexplained increases in serum creatinine were not evident, but potentially included surgery itself (nephrectomy), patient condition, or the concomitant administration of renally cleared medications or drugs that affect renal blood flow. IMPLICATIONS: We studied the safety and tolerance of an investigational drug, RSR13 (Allos Therapeutics, Denver, CO), in general surgery patients. This drug, which increases the amount of oxygen available to the body, was well tolerated by the 17 patients who received it. There were clinically relevant increases in serum creatinine in 3 patients, indicating a decrease in renal function, but these increases were short-lived and resolved without treatment.

The Effect of Anxiety and Personality on the Pharmacokinetics of Oral Midazolam—Martens-Lobenhoffer J, Eisenhardt S, Troger U, Rose W, Meyer FP. Anesth Analg 2001 Mar;92(3):621-624.

We investigated the relationship between the pharmacokinetic variables of oral midazolam and patients' state/trait anxiety and personality. Twenty-six patients received the standard 15-mg oral dose for anxiolysis on the evening before otorhinolaryngological surgery. Blood samples were taken over a 9-h period after the administration, and the samples were analyzed for concentrations of midazolam and its two main metabolites by using a gas chromatography-mass spectrometry procedure. The pharmacokinetic variables maximum concentration, time to reach the maximum concentration, the elimination half-life, and the area under the curve were calculated from these data. When the patients were divided into groups with respect to their anxiety and personality scores, no significant differences in the pharmacokinetic variables of midazolam could be found. Only small, insignificant changes in the maximum concentrations were found with respect to nervousness and emotionality. We conclude that personality traits and anxiety levels had no effect on the pharmacokinetic variables of midazolam. IMPLICATIONS: We conclude that personality traits and anxiety levels had no effect on the pharmacokinetic variables of midazolam. Therefore, it is not necessary to obtain anxiety or personality scores to find the proper midazolam dose for the individual patient.

Diaphragm Movement Before and After Cholecystectomy: A Sonographic Study—Ayoub J, Cohendy R, Prioux J, Ahmaidi S, Bourgeois JM, Dauzat M, et al. Anesth Analg 2001 Mar;92(3):755-761.

Respiratory disorders after abdominal surgery are commonly explained by changes in diaphragmatic movement that are difficult to demonstrate and quantify. Our aim was thus to quantify these changes using a noninvasive method. We used M-mode sonography for the prospective study to measure diaphragmatic amplitude in 14 patients before and after cholecystectomy. During quiet breathing, the diaphragm inspiratory amplitude (DIA) was significantly decreased after surgery from 1.4 ± 0.2 cm to 1 ± 0.1 cm and from 1.6 ± 0.3 cm to 1.2 ± 0.3 cm in the Laparoscopic and Open Cholecystectomy groups, respectively. The total time cycle of diaphragmatic motion decreased significantly in the two groups. The DIA also decreased significantly during deep breathing after cholecystectomy from 6.0 ± 0.8 cm to 3.0 ± 1.8 cm and from 6.1 ± 1.3 cm to 3.1 ± 1.6 cm in the Laparoscopic and Open Cholecystectomy groups, respectively. The six patients who underwent spirometric examination showed, during quiet breathing, a significant decrease in DIA without change in tidal volume, i.e., 0.51 ± 0.08 L to 0.45 ± 0.08 L. We found a significant decrease in DIA after cholecystectomy and a significant interindividual correlation between DIA during deep inspiration and inspiratory capacity. Using M-mode sonography techniques, we were able to demonstrate changes in diaphragmatic mobility after laparoscopic or open cholecystectomy. IMPLICATIONS: Cholecystectomy at times results in impaired respiratory and diaphragmatic functions. The techniques currently used to study these repercussions are both laborious and invasive. Our sonographic technique is completely noninvasive and can be used to study diaphragm morphology and movement in real time.

Early Childhood Infectious Diseases and the Development of Asthma up to School Age: A Birth Cohort Study—Illi S, von Mutius E, Lau S, Bergmann R, Niggemann B, Sommerfeld C, Wahn U. BMJ 2001 Feb 17;322(7283):390-395.

OBJECTIVE: To investigate the association between early childhood infections and subsequent development of asthma. DESIGN: Longitudinal birth cohort study. SETTING: Five children's hospitals in five German cities. PARTICIPANTS: 1314 children born in 1990 followed from birth to the age of 7 years. MAIN OUTCOME MEASURES: Asthma and asthmatic symptoms assessed longitudinally by parental questionnaires; atopic sensitisation assessed longitudinally by determination of IgE concentrations to various allergens; bronchial hyperreactivity assessed by bronchial histamine challenge at age 7 years. RESULTS: Compared with children with ≤ 1 episode of runny nose before the age of 1 year, those with ≥ 2 episodes were less likely to have a doctor's diagnosis of asthma at 7 years old (odds ratio 0.52 (95% confidence interval 0.29 to 0.92)) or to have wheeze at 7 years old (0.60 (0.38 to 0.94)), and were less likely to be atopic before the age of 5 years. Similarly, having ≥ 1 viral infection of the herpes type in the first 3 years of life was inversely associated with asthma at age 7 (odds ratio 0.48 (0.26 to 0.89)). Repeated lower respiratory tract infections in the first 3 years of life showed a positive association with wheeze up to the age of 7 years (odds ratio 3.37 (1.92 to 5.92) for ≥ 4 infections v ≤ 3 infections). CONCLUSION: Repeated viral infections other than lower respiratory tract infections early in life may reduce the risk of developing asthma up to school age.

Predicted Impact of Attaining Smoking Reduction Goals on Mortality—Silverstein MD, Nietert PJ, Zoller JS, Silvestri GA. South Med J 2001 Feb;94(2):176-183.

The impact of reducing smoking initiation, increasing smoking cessation, and combination approaches on life expectancy, deaths averted, and life-years gained in a birth cohort of 50,000 persons and in the state population (3.6 million) were analyzed. A 60% reduction in initiation of

smoking in adolescents would increase life expectancy by 0.42 years. Over the next 100 years, there would be an additional 18,000 years of life for a birth cohort and an additional 675,000 years of life for the state's population. The reduction in mortality, however, would not begin before 35 years, and only 25% of the benefit would occur in the next 70 years. An increase in smoking cessation would have a smaller impact that would occur sooner. Maximum reduction in mortality could be achieved by reducing initiation and increasing cessation at all ages, but a reduction in mortality would not occur for several decades.

Percutaneous Dilatational Tracheostomy in a Community Hospital Setting—Thompson EC, Fernandez LG, Norwood S, Wilkins H 3rd, Vallina VL. South Med J 2001 Feb;94(2):208-211.

BACKGROUND: Over the past 15 years, many large university hospitals have reported their experience with percutaneous dilatational tracheostomy (PDT). The purposes of this study are to evaluate the safety of PDT in a non-university hospital setting and to compare our results with those published in the literature. METHODS: The study was done by retrospective chart review. RESULTS: Over a 6-year period, 300 PDTs were done in two community hospitals in Tyler, Texas. There was one death and 12 complications. Comparison of our results and those reported in five recently published articles in the literature showed no significant difference in mortality rate, pneumothorax, bleeding, paratracheal placement, dislodgement, or cellulitis. There was a trend toward a significantly lower incidence of paratracheal placement using bronchoscopic guidance. CONCLUSION: Bedside PDT with bronchoscopic guidance can be safely done in a community hospital setting.

Disseminated *Pseudomonas Aeruginosa* and Necrotizing Pneumonia with Complete Recovery—Kumar PD, Ravakhah K, West BC. South Med J 2001 Feb;94(2):229-232.

Pseudomonas aeruginosa pneumonia and recovery with treatment are rare in healthy individuals. We report the case of a 59-year-old man with *P aeruginosa* skin infection and sepsis, later giving rise to necrotizing pneumonia by hematogenous spread. He responded to prolonged intensive care and 3 weeks of piperacillin-tazobactam and tobramycin therapy. There was no evidence of immunosuppression other than that caused by alcoholism in this unusual case. The resulting cavity healed completely by fibrosis in 1 year.

Aerosolized Amikacin in the Treatment of Pseudomonas Pneumonia in the Nursing Home Setting—Standridge JB, Aliff CL. South Med J 2001 Feb;94(2):244-6.

Studies have shown that aerosolized aminoglycosides represent a safe and effective means of treating pneumonia due to Pseudomonas sp. Aerosolized aminoglycosides have been shown to improve clinical outcome, with less risk of nephrotoxicity relative to parenteral aminoglycosides. Apparently less drug resistance is associated with the use of aerosolized aminoglycosides. Cost factors favor aerosolized delivery methods. The full recovery experienced by the patient in this case study suggests that aerosolized amikacin may be a safe, efficacious, and cost-effective means of treating pseudomonal pneumonia in geriatric patients. Controlled clinical trials should be conducted to further investigate this treatment regimen.

Improving Survival from Sudden Cardiac Arrest: The Role of the Automated External Defibrillator—Marenco JP, Wang PJ, Link MS, Homoud MK, Estes NA 3rd. JAMA 2001 Mar 7;285(9):1193-1200.

CONTEXT: Sudden cardiac death is a major public health problem in the United States, and improving survival after out-of-hospital cardiac arrest has been the subject of intense study. Early defibrillation has been shown to be critical to improving survival. Use of automated external defibrillators (AEDs) has become an important component of emergency medical systems, and recent advances in AED technology have allowed expansion of AED use to nontraditional first responders and the lay public. OBJECTIVES: To examine advancements in AED technology, review the impact of AEDs on time to defibrillation and survival, and explore the future role of AEDs in the effort to improve survival following sudden cardiac arrest. DATA SOURCES: MEDLINE was searched for articles from 1966 through December 2000 (Medical Subject Headings: electric countershock, heart arrest, resuscitation, emergency medical services; keywords: automatic external defibrillator, automated external defibrillator, public access defibrillation). Reference lists of relevant articles, news releases, and product information from manufacturers were also reviewed. STUDY SELECTION: Initial MEDLINE search produced 4816 articles, from which 101 articles were selected for referencing based on having been published in a peer-reviewed journal and on relevance to the subject of the manuscript as determined by all 5 authors. DATA EXTRACTION: All studies were critically reviewed for relevance, accuracy, and quality of data and study design by all authors. DATA SYNTHESIS: Recent advances in AED technology and design have resulted in marked simplification of AED operation, improvements in accuracy and effectiveness, and reductions in cost. Use of AEDs by first responders and laypersons has reduced time to defibrillation and improved survival from sudden cardiac arrest in several communities. Initial studies of the cost-effectiveness of AED use in comparison with other commonly used treatments are favorable. CONCLUSION: The AED represents an efficient method of delivering defibrillation to persons experiencing out-of-hospital cardiac arrest and its use by both traditional and nontraditional first responders appears to be safe and effective. The rapidly expanding role of AEDs in traditional emergency medical systems is supported by the literature, and initial studies of public access to defibrillation offer hope that further improvements in survival after sudden cardiac death can be achieved.

Monitoring and Ensuring Safety During Clinical Research—Morse MA, Califf RM, Sugarman J. JAMA 2001 Mar 7;285(9):1201-1205.

Increased numbers of clinical trials, many of which are large, multicenter, and sometimes international, and the marked shift of funding for clinical trials to industry have made apparent the inadequacy of mechanisms for protecting human subjects that were developed when clinical research was generally carried out on a small scale at single institutions. To address concerns regarding the protection of human subjects, a group of professionals with expertise in various aspects of clinical trials was assembled in May 2000. Participants described and evaluated the mechanisms by which clinical trials are monitored, focusing on adverse event reporting and the processes by which various parties with oversight responsibilities interact in the course of these trials. In this article, we describe the manner in which adverse event reporting might function to enhance safety and the role of data monitoring committees in using aggregate data from these reports, outline the problems that now exist for institutional review boards as they are faced with multiple adverse event reports from clinical trials while conducting continuing review, and offer recommendations for improving the current approach.

Conflict Resolution at the End of Life—Fetters MD, Churchill L, Danis M. Crit Care Med 2001;29(5):921-925.

OBJECTIVE: Limited empirical research has examined how decisions are made when the preferences of terminally ill patients conflict with physicians' recommendations. This study sought to investigate physicians' strategies for resolving conflicts with dying patients. DESIGN: Cross-sectional, qualitative interviews. SUBJECTS: Subjects were 158 physicians caring for at least one terminally ill patient. SETTING: University medical center. MEASUREMENTS AND MAIN RESULTS: We

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analyzed physicians' responses to the open-ended interview questions, "How do you handle a situation when a patient wants a treatment that you believe does not provide any benefit?" and "How do you handle a situation when a patient does not want a treatment you think would be beneficial?" For patient requests of nonbeneficial treatments, physicians reported the following as important: negotiating with and educating patients (71%), deferring to patient requests for benign or uncomplicated treatments (34%), convincing patients to forgo treatments (33%), refusing patient requests for nonbeneficial treatment (22%), using family influence (16%), not offering futile treatments (13%), and referring to other physicians for disputed care (9%). Potential harm (23%) and cost of treatment (18%) were reasons cited for withholding treatments. In response to patient refusals of beneficial treatments, physicians report the following as important: negotiating with patients (59%), convincing patients to receive treatment (41%), assessing patient competence (32%), using family influence (27%), and referring to other physicians (21%). CONCLUSIONS: Physicians vary in the communication and negotiation strategies they use when their medical judgment conflicts with dying patients' preferences. Medical ethicists could play a greater role in teaching ethically important communication skills. Physicians providing care at the end of life report strategies for respecting patients that reflect graduated degrees of accommodation tailored to the costliness and riskiness of requests; they are most accepting of patient requests for benign, technically easy, inexpensive, and medically effective treatments.

A Prospective, Randomized Study Comparing Percutaneous with Surgical Tracheostomy in Critically Ill Patients—Freeman BD, Isabella K, Cobb JP, Boyle WA 3rd, Schmieg RE Jr, Kolleff MH, et al. Crit Care Med 2001;29(5):926-930.

OBJECTIVE: To determine the relative cost-effectiveness of percutaneous dilational tracheostomy (PDT) and surgical tracheostomy (ST) in critically ill patients. DESIGN: Prospective randomized study. SETTING: Medical, surgical, and coronary intensive care units at Barnes-Jewish Hospital, a tertiary care medical center. PATIENTS: Eighty critically ill mechanically ventilated patients requiring elective tracheostomy. INTERVENTIONS: Randomization to either PDT performed in the intensive care unit or ST performed in the operating room. MEASUREMENTS AND MAIN RESULTS: Treatment groups were well matched with respect to age (PDT, 65.44 ± 2.82 [mean ± se] years; ST, 61.4 ± 2.89 years, p = Ns), gender (PDT, 45% males; ST, 47.5% males, p = NS), severity of illness (Acute Physiology and Chronic Health Evaluation II score: PDT, 16.87 ± 0.84; ST, 17.88 ± 0.92, p = NS), and principle diagnosis. PDT was performed more quickly (PDT, 20.1 ± 2.0 mins; ST, 41.7 ± 3.9 mins, p < 0.0001) and was associated with lower patient charges than ST (total patient charges: PDT, 1,569 dollars ± 157 dollars vs. ST, 3,172 dollars ± 114 dollars; equipment/supply charges: PDT, 688 dollars ± 103 dollars vs. ST, 1,526 dollars ± 87 dollars; professional charges: PDT, 880 dollars ± 54 dollars vs. ST, 1,647 dollars ± 50 dollars; p <0.0001 for all). There were no differences in days intubated before tracheostomy (PDT, 12.7 ± 1.1 days; ST, 15.6 ± 1.9, p = 0.20), intensive care unit length of stay (PDT, 24.5 ± 2.5 days; ST, 28.5 ± 3.1 days, p = 0.33), or hospital length of stay (PDT 49.7 ± 4.2 days; ST, 43.7 ± 3.5 days, p = 0.28) when we compared these two techniques. CONCLUSIONS: PDT is a cost-effective alternative to ST. The reduction in patient charges associated with PDT in this study resulted from the procedure being performed in the intensive care unit, thus eliminating the need for operating room facilities and personnel. PDT may become the procedure of choice for electively establishing tracheostomy in the appropriately selected patient who requires long-term mechanical ventilation.

Report on the Development of a Procedure to Prevent Placement of Feeding Tubes into the Lungs Using End-Tidal CO_2 Measurements—Burns SM, Carpenter R, Truwit JD. Crit Care Med 2001;29(5):936-939.

OBJECTIVE: To determine the accuracy of a technique using capnography to prevent inadvertent placement of small-bore feeding tubes and Salem sump tubes into the lungs. SETTING: Twelve-bed medical intensive care unit (MICU) in a 557-bed teaching hospital. PATIENTS: A total of 25 ventilated adult MICU patients were studied-5 in phase 1 and 20 in phase 2. DESIGN: Phase 1 tested the ability of the end-tidal CO_2 ($etCO_2$) monitor to detect flow (and thus accurately detect CO_2) through small-bore feeding tubes. A small-bore feeding tube, with stylet in place, was placed 5 cm through the top of the tracheostomy tube ventilator adapter in five consecutive patients. The distal end of the feeding tube was attached to the $etCO_2$ monitor. The $etCO_2$ level and waveform were assessed and recorded. Because CO_2 waveforms were successfully detected, a convenience sample of 20 adult MICU patients who were having feeding tubes placed (13 Salem sump tubes, 7 small-bore feeding tubes) was then studied. The technique consisted of attaching the $etCO_2$ monitor to the tubes and observing the $etCO_2$ waveform throughout placement. RESULTS: The study hypothesis was supported. Of the seven small-bore feeding tubes tested, all were successfully placed on initial insertion. Placement was confirmed by absence of an $etCO_2$ waveform and by radiograph. Of the 13 Salem sump tubes, 9 were placed successfully on first attempt and confirmed by absence of CO_2 and by air bolus and aspiration of stomach contents. $etCO_2$ waveforms were detected with insertion of four of the Salem sump tubes; the tubes were immediately withdrawn, and placement was reattempted until successful. CONCLUSIONS: The technique described is a simple, cost-effective method of assuring accurate gastric tube placement in critically ill patients.

Assessment of Two Hand Hygiene Regimens for Intensive Care Unit Personnel—Larson EL, Aiello AE, Bastyr J, Lyle C, Stahl J, Cronquist A, et al. Crit Care Med 2001;29(5):944-951.

OBJECTIVE: To compare skin condition and skin microbiology among intensive care unit personnel using one of two randomly assigned hand hygiene regimens: a 2% chlorhexidine gluconate (CHG)-containing traditional antiseptic wash and a waterless handrub containing 61% ethanol with emollients (ALC). DESIGN: Prospective, randomized clinical trial. SETTING: Two critical care units (medical and surgical) in a large, metropolitan academic health center in Manhattan. SUBJECTS: Fifty staff members (physicians, nurses, housekeepers, respiratory therapists) working full time in the intensive care unit. INTERVENTIONS: One of two hand hygiene regimens randomly assigned for four consecutive weeks. MEASUREMENTS AND MAIN RESULTS: The two outcomes were skin condition (measured by two tools: Hand Skin Assessment form and Visual Skin Scaling form) and skin microbiology. Samples were obtained at baseline, on day 1, and at the end of wks 2 and 4. Participants in the ALC group had significant improvements in the Hand Skin Assessment scores at wk 4 (p = 0.04) and in Visual Skin Scaling scores at wks 3 (p = 0.01) and 4 (p = 0.0005). There were no significant differences in numbers of colony-forming units between participants in the CHG or ALC group at any time period. The ALC regimen required significantly less time than the CHG regimen (mean: 12.7 secs and 21.1 secs, respectively; p = 0.000) and resulted in a 50% reduction in material costs. CONCLUSIONS: Changes in hand hygiene practices in acute care settings from the traditional antiseptic wash to use of plain, mild soap and an alcohol-based product should be considered. Further research is needed to examine the association between use of antiseptic products for hand hygiene of staff and reductions in nosocomial infection rates among patients.

Breathing Pattern and Perception at Different Levels of Volume Assist and Pressure Support in Volunteers—Mols G, Vetter T, Haberthur C, Geiger K, Guttmann J. Crit Care Med 2001;29(5):982-988.

OBJECTIVE: Volume assist (VA) amplifies the breathing effort whereas pressure support ventilation (PSV) provides a fixed, effort-independent ventilatory support. According to the concept of VA, its level should

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compensate for the pathologically increased (additional) elastance (Eadd). However, it is unclear whether breathing subjects prefer an exact compensation of Eadd and whether they are able to adjust the support level by themselves. DESIGN: Prospective, interventional study. SETTING: Laboratory. SUBJECTS: Twelve healthy volunteers, nine females, three males, aged 21-33 yrs. INTERVENTIONS: Increased Eadd was generated by banding of the thorax and abdomen. Volunteers breathed via a mouthpiece with VA or PSV using a positive end-expiratory pressure of 5 cm H_2O (0.5 kPa). The study was subdivided into two parts. In part I, volunteers were instructed to adjust the level of VA and PSV themselves starting from three different, randomly applied levels in each mode (2, 8, 14 cm H_2O or cm H_2O/L; 0.2, 0.8, 1.4 kPa[/L]). In part II, 20 levels of VA and PSV (1-20 cm H_2O or cm H_2O/L, 0.1-2 kPa[/L]) were randomly selected by an investigator and estimated by the volunteers using a visual analog scale. Additionally, the breathing pattern was characterized. MEASUREMENTS AND MAIN RESULTS: Eadd (7.1 ± 1.5 cm H_2O/L [0.7 ± 0.2 kPa/L], mean ± sd) corresponded almost exactly to the "self-adjusted" VA level of part I (7.0 ± 3.3 cm H_2O/L [0.7 ± 0.3 kPa/L]) and to the adequate level of part II (8-9 cm H_2O/L [0.8-0.9 kPa/L]). The accordant PSV levels were 5.7 ± 2.6 cm H_2O (0.6 ± 0.3 kPa) and 6-7 cm H_2O (0.6-0.7 kPa). The breathing pattern was less influenced by changes of the support level with VA compared with PSV, which may explain in part the greater comfort of VA. CONCLUSIONS: We confirmed the theoretical assumption that VA should be adapted to Eadd. Furthermore, we demonstrated that conscious subjects are able to adjust the level of VA and PSV themselves.

Altered Alveolar Mechanics in the Acutely Injured Lung—Schiller HJ, McCann UG 2nd, Carney DE, Gatto LA, Steinberg JM, Nieman GF. Crit Care Med 2001;29(5):1049-1055.

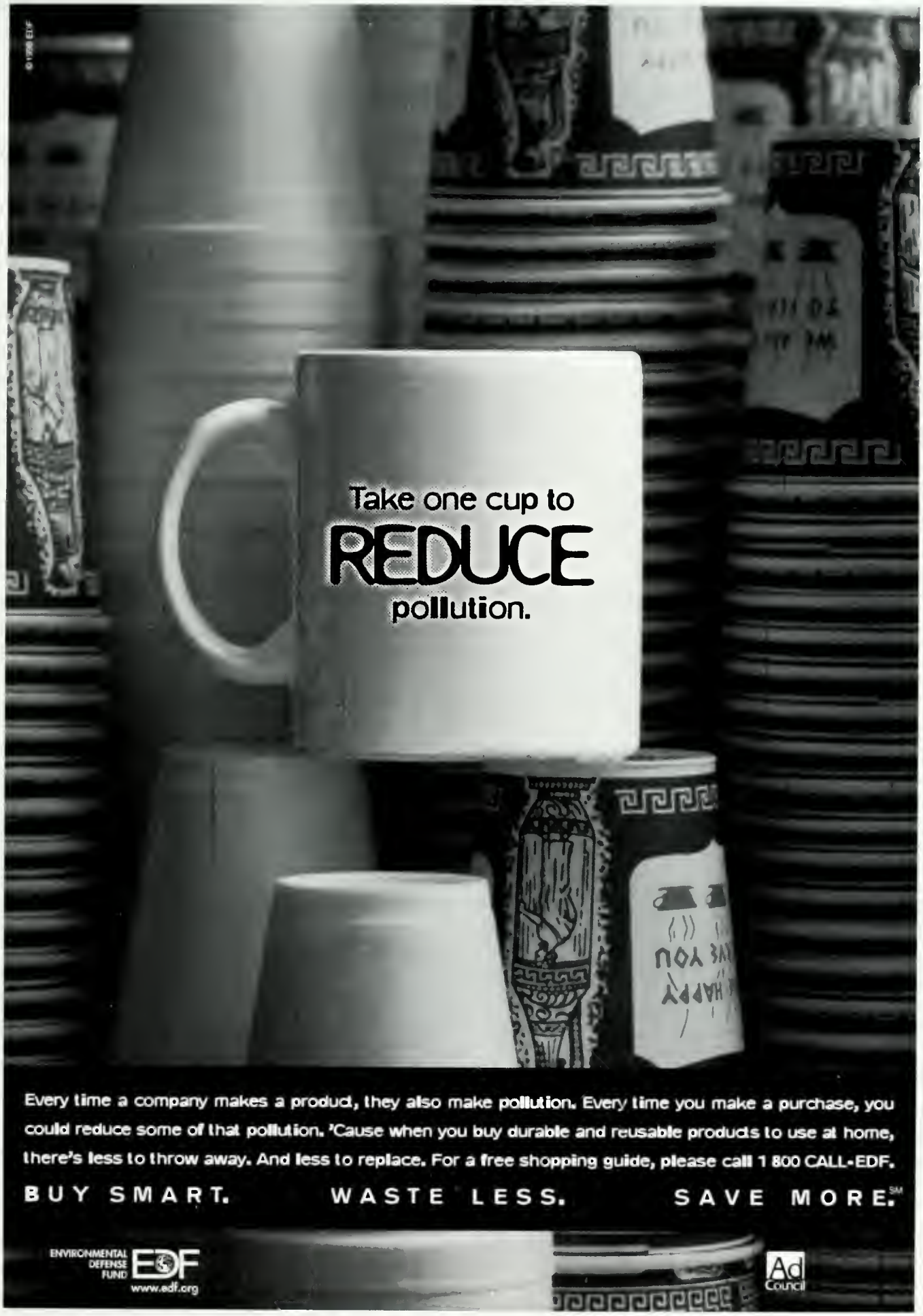
OBJECTIVES: Alterations in alveolar mechanics (i.e., the dynamic change in alveolar size during tidal ventilation) are thought to play a critical role in acute lung injuries such as acute respiratory distress syndrome (ARDS). In this study, we describe and quantify the dynamic changes in alveolar mechanics of individual alveoli in a porcine ARDS model by direct visualization using in vivo microscopy. DESIGN: Prospective, observational, controlled study. SETTING: University research laboratory. SUBJECTS: Ten adult pigs. INTERVENTIONS: Pigs were anesthetized and placed on mechanical ventilation, underwent a left thoracotomy, and were separated into the following two groups post hoc: a control group of instrumented animals with no lung injury (n = 5), and a lung injury group in which lung injury was induced by tracheal Tween instillation, causing surfactant deactivation (n = 5). Pulmonary and systemic hemodynamics, blood gases, lung pressures, subpleural blood flow (laser Doppler), and alveolar mechanics (in vivo microscopy) were measured in both groups. Alveolar size was measured at peak inspiration (I) and end expiration (E) on individual subpleural alveoli by image analysis. Histologic sections of lung tissue were taken at necropsy from the injury group. MEASUREMENTS AND MAIN RESULTS: In the acutely injured lung, three distinct alveolar inflation-deflation patterns were observed and classified: type I alveoli (n = 37) changed size minimally (I - EΔ = 367 ± 88 μm^2) during tidal ventilation; type II alveoli (n = 37) changed size dramatically (I - EΔ = 9326 ± 1010 μm^2) with tidal ventilation but did not totally collapse at end expiration; and type III alveoli (n = 12) demonstrated an even greater size change than did type II alveoli (I - EΔ = 15,418 ± 1995 μm^2), and were distinguished from type II in that they totally collapsed at end expiration (atelectasis) and reinflated during inspiration. We have termed the abnormal alveolar inflation pattern of type II and III alveoli "repetitive alveolar collapse and expansion" (RACE). RACE describes all alveoli that visibly change volume with ventilation, regardless of whether these alveoli collapse totally (type III) at end expiration. Thus, the term "collapse" in RACE refers to a visibly obvious collapse of the alveolus during expiration, whether this collapse is total or partial. In the normal lung, all alveoli measured exhibited type I mechanics. Alveoli were significantly larger at peak inspiration in type II (18,266 ± 1317 μm^2, n = 37) and III (15,418 ± 1995 μm^2, n = 12) alveoli as compared with type I (8214 ± 655 μm^2, n = 37). Tween caused a heterogenous lung injury with areas of normal alveolar mechanics adjacent to areas of abnormal alveolar mechanics. Subsequent histologic sections from normal areas exhibited no pathology, whereas lung tissue from areas with RACE mechanics demonstrated alveolar collapse, atelectasis, and leukocyte infiltration. CONCLUSION: Alveolar mechanics are altered in the acutely injured lung as demonstrated by the development of alveolar instability (RACE) and the increase in alveolar size at peak inspiration. Alveolar instability varied from alveolus to alveolus in the same microscopic field and included alveoli that changed area greatly with tidal ventilation but remained patent at end expiration and those that totally collapsed and reexpanded with each breath. Thus, alterations in alveolar mechanics in the acutely injured lung are complex, and attempts to assess what may be occurring at the alveolar level from analysis of inflection points on the whole-lung pressure/volume curve are likely to be erroneous. We speculate that the mechanism of ventilator-induced lung injury may involve altered alveolar mechanics, specifically RACE and alveolar overdistension.

Use of Computerized Tomography and Chest X-Rays in Evaluating Efficacy of Aerosolized Recombinant Human DNase in Cystic Fibrosis Patients Younger than Age 5 years: A Preliminary Study—Nasr SZ, Kuhns LR, Brown RW, Hurwitz ME, Sanders GM, Strouse PJ. Pediatr Pulmonol 2001;31(5):377-382.

The aim of this study was to evaluate the ability of high-resolution computerized tomography (HRCT) of the chest and chest x-rays (CXR) to determine efficacy of inhaled recombinant human DNase (rhDNase) in cystic fibrosis (CF) patients younger than 5 years of age. A randomized, double-blind, placebo-controlled pilot study of 12 patients with CF younger than 5 years of age, attending the University of Michigan Cystic Fibrosis Center (Ann Arbor, MI) was conducted. The changes in the HRCT and CXR score from baseline to day 100 of therapy were assessed using a previously validated scoring system. The mean changes of HRCT scores between the rhDNase and placebo groups were found to be significant at the 95% level, with mean change ± SE mean of - 1.00 ± 0.53 and 0.58 ± 0.24 for rhDNase and placebo groups, respectively ($p = 0.02$). The difference in CXR score was not significant between the two groups. An analysis was performed to relate HRCT subscores to CXR score; only thickening of the intra-interlobular septae was significantly correlated with the total CXR score ($r = - 0.7$, $p < 0.01$). There was improvement in the parents' assessments of the patients' well-being, with improvement in physical activity, decreased cough, sleep quality, and appetite in those subjects receiving rhDNase. We conclude that the administration of rhDNase was associated with improvement in the HRCT scan in CF patients younger than 5 years of age. Findings indicate that HRCT of the chest is useful and sensitive in studying responses to therapy in patients with CF lung disease. To our knowledge, this is the first report of the use of HRCT to assess the effectiveness of a therapeutic modality in so young a CF patient population.

Bronchoscopically Administered Recombinant Human DNase for Lobar Atelectasis in Cystic Fibrosis—Slattery DM, Waltz DA, Denham B, O'Mahony M, Greally P. Pediatr Pulmonol 2001;31(5):383-388.

Lobar atelectasis is a common complication of cystic fibrosis. The majority of cases respond to intravenous antibiotics and chest physiotherapy. In a subgroup of patients, atelectasis is resistant to medical therapy, and its persistence in the pediatric population is associated with a poor prognosis. Bronchoscopic instillation of human recombinant DNase expanded atelectatic lobes in three children resistant to at least 2 weeks of medical therapy. This method of administration of DNase has been successful in resistant cases of lobar atelectasis in patients with chronic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obstructive pulmonary disease, quadriplegia, and status asthmaticus. Purulent cystic fibrosis sputum has a very high DNA content, and DNA has been shown to become more pourable in vitro when treated with rhDNase. Bronchoscopic instillation of rhDNase should be considered in cases of persistent lobar atelectasis unresponsive to medical therapy.

Non-Invasive Pressure Support Ventilation in Severe Community-Acquired Pneumonia—Jolliet P, Abajo B, Pasquina P, Chevrolet JC. Intensive Care Med 2001;27(5):812–821.

OBJECTIVE: To explore three aspects of non-invasive pressure support ventilation (NIPSV) applied by face mask to patients with acute respiratory failure (ARF) due to severe community-acquired pneumonia (CAP): (1) the initial acute effects on respiratory rate, gas exchange and hemodynamics, (2) the clinical course and outcome during ICU and hospital stay, (3) the nursing workload as measured by the daily PRN 87 (Project Research in Nursing) score. SETTING: Medical ICU, University Hospital. DESIGN: Prospective, observational study. PATIENTS: Patients without any prior history of chronic lung disease, consecutively admitted to the ICU to receive NIPSV for ARF due to severe CAP. MEASUREMENTS AND RESULTS: (means ± SD): Twenty-four patients aged 49±17 years, admission APACHE II 13±5, were included. Admission P_{aO_2}/F_{IO_2}, alveolar-arterial oxygen difference (DA-aO_2) and P_{aCO_2} were 104±48, 447±120 and 40±10 mmHg, respectively. All patients were normotensive. During the initial NIPSV trial respiratory rate decreased from 34±8 to 28±10 breaths/min ($p < 0.001$) and arterial oxygenation improved (P_{aO_2}/F_{IO_2} 104±48 vs 153±49, DA-aO_2 447±120 vs 370±180 mm Hg, $p < 0.001$) while P_{aCO_2} remained unchanged. There were no hemodynamic effects. Subsequently, a total of 133 NIPSV trials were performed (median duration 55 min, range 30–540 min) over 1–7 days. No complication occurred during NIPSV. Sixteen patients were intubated (66%) 1.3±1 days after inclusion. Upon inclusion, the patients who were subsequently intubated were older (55±15 vs 37±12 years) and more severely hypoxemic (63±11 vs 80±15 mmHg, $p < 0.05$) than those not requiring intubation. Eight patients died (33%), all in the intubated group. Median lengths of stay in the ICU and hospital were longer in intubated patients (ICU 16 days, range 3–64 vs 6 days, range 3–7, $p < 0.05$; hospital 23 days, range 9–77 vs 9.5 days, range 4–42, $p < 0.05$). Mean daily total PRN points were stable throughout the NIPSV period and were not different between the groups. Only 14% of PRN points resulted from respiratory therapy interventions. PRN score was higher during the first 24 h following intubation than during the first 24 h of NIPSV (278±55 vs 228±24 points, $p < 0.05$). CONCLUSION: Despite initial improvement in arterial oxygenation with NIPSV in patients with ARF due to severe CAP, the intubation rate is high. However, the more favorable outcome and shorter ICU and hospital stays when intubation is avoided, as well as the short delay required to assess the success or failure of NIPSV warrants a trial of NIPSV in this setting. The nursing workload remains stable during NIPSV and does not result predominantly from respiratory therapy interventions.

The Value of the Chloride: Sodium Ratio in Differentiating the Aetiology of Metabolic Acidosis—Durward A, Skellett S, Mayer A, Taylor D, Tibby SM, Murdoch IA. Intensive Care Med 2001;27(5):828–835.

OBJECTIVE: Stewart's physicochemical approach to acid-base balance defines the aetiology of a metabolic acidosis by quantifying anions of tissue acids (TA), which consist of unmeasured anions (UMA) and/or lactate. We hypothesised that an increase in TA during metabolic acidosis would lead to a compensatory fall in the plasma chloride (Cl) relative to sodium (Cl:Na ratio) in order to preserve electro-neutrality. Thus, the Cl:Na ratio could be used as a simple alternative to the anion gap in identifying raised TA. PATIENTS: Two hundred and eighty two consecutive patients who were admitted to our Paediatric Intensive Care were enrolled in the study. INTERVENTIONS: We obtained 540 samples (admission n = 282, 24 h n = 258) for analysis of blood chemistry, lactate and quantification of TA and UMA. Samples were subgrouped into those with metabolic acidosis (standard bicarbonate < 22 mmol/L) either with or without increased UMA (> 3 mEq/L). MEASUREMENTS AND RESULTS: Metabolic acidosis occurred in 46% of samples, of which 52.3% (120/230) had increased UMA. The dominant component of TA was UMA rather than lactate, and these two components did not always rise in tandem. Our hypothesis of relative hypochloraemia was supported by a lower Cl:Na ratio ($p < 0.0001$) but not a lower absolute Cl ($p = 0.5$) in the acidotic subgroup with raised UMA, and by the inverse relationship between TA and the Cl:Na ratio. (coefficient of determination (r^2) = 0.37, $p < 0.0001$). The best discriminator for the presence of raised TA was the albumin-corrected anion gap (AG_{corr}), however, this could not track changes in TA with clinical accuracy. The Cl:Na ratio discriminated reasonably well, a ratio of < 0.75 identified TA (positive predictive value (PPV) 88%) with a likelihood ratio (LR) similar to the AG (7.8 vs7.4). Conversely, a high ratio (> 0.79) excluded TA (PPV 81%, LR 4.5). Base deficit (BD) and lactate performed poorly. CONCLUSION: In metabolic acidosis due to TA, plasma Cl concentration decreases relative to sodium. The Cl:Na ratio is a simple alternative to the AG for detecting TA in this setting.

Validating the Sedation-Agitation Scale with the Bispectral Index and Visual Analog Scale in Adult ICU Patients After Cardiac Surgery—Riker RR, Fraser GL, Simmons LE, Wilkins ML. Intensive Care Med 2001;27(5):853–858.

OBJECTIVE: To validate the Sedation-Agitation Scale (SAS) with the Visual Analog Scale (VAS) and Bispectral Index (BIS) in adult ICU patients after cardiac surgery. DESIGN: Prospective study comparing blinded evaluations of the SAS, VAS and BIS. SETTING: Forty-two-bed multidisciplinary ICU. PATIENTS AND PARTICIPANTS: Convenience sample of 39 adults after cardiac surgery. MEASUREMENTS AND RESULTS: Bispectral Index 3.2 was continuously recorded using the Aspect A-1000 and evaluators were blinded to this value. The bedside nurse and a trained researcher independently rated wakefulness using a 100 mm VAS upon patient arrival on the ICU, at first awakening, when ventilator weaning was started and after extubation; the researcher also evaluated patients using SAS. Upon arrival on the ICU, the median SAS score was 2 (interquartile range = 1–3), the mean VAS was 26±30 and the mean BIS was 70±16. Twenty-four patients underwent a trial of weaning from mechanical ventilation with a SAS of 4 (IQR = 4), VAS of 86±12 and BIS of 87±10. SAS correlated well with VAS performed by one researcher ($r = 0.91$, $p < 0.001$) or by 19 different bedside nurses ($r = 0.43$, $p < 0.001$) and with BIS 3.2 ($r = 0.60$, $p < 0.001$). The correlation between SAS and BIS was reduced in patients with above average electromyogram (EMG) power. As a measure of construct validity, significant differences were noted for the BIS, SAS, VAS and EMG between ICU arrival and extubation (all $p < 0.001$). CONCLUSIONS: Sedation-Agitation Scale and BIS are valid measures of wakefulness after cardiac surgery, but EMG interference may affect the accuracy of BIS for a small percentage of patients not receiving neuromuscular blockade.

Intensive Care Delirium Screening Checklist: Evaluation of a New Screening Tool—Bergeron N, Dubois MJ, Dumont M, Dial S, Skrobik Y. Intensive Care Med 2001;27(5):859–864.

OBJECTIVE: Delirium in the intensive care unit is poorly defined. Clinical evaluation is difficult in the setting of unstable, often intubated patients. A screening tool may improve the detection of delirium. METHOD: We created a screening checklist of eight items based on DSM criteria and features of delirium: altered level of consciousness, inattention, disorientation, hallucination or delusion, psychomotor agitation or retardation, inappropriate mood or speech, sleep/wake cycle disturbance,

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and symptom fluctuation. During 3 months, all patients admitted to a busy medical/surgical intensive care unit were evaluated, and the scale score was compared to a psychiatric evaluation. RESULTS: In 93 patients studied, 15 developed delirium. Fourteen (93%) of them had a score of 4 points or more. This score was also present in 15 (19%) of patients without delirium, 14 of whom had a known psychiatric illness, dementia, a structural neurological abnormality or encephalopathy. A ROC analysis was used to determine the sensitivity and specificity of the screening tool. The area under the ROC curve is 0.9017. Predicted sensitivity is 99% and specificity is 64%. CONCLUSION: This study suggests that the Intensive Care Delirium Screening Checklist can easily be applied by a clinician or a nurse in a busy critical care setting to screen all patients even when communication is compromised. The tool can be utilized quickly and helps to identify delirious patients. Earlier diagnosis may lead to earlier intervention and better patient care.

The Impact of Organisational Change on Outcome in an Intensive Care Unit in the United Kingdom—Baldock G, Foley P, Brett S. Intensive Care Med 2001;27(5):865–872.

OBJECTIVES: To study the change in outcome for patients admitted to an intensive care unit following the establishment of a team of resident medical staff and a change from an "open" to a "closed" organisational format. DESIGN: Database review of prospectively collected data. Setting: Intensive care unit of a postgraduate teaching hospital. SUBJECTS: 1134 admissions to the intensive care unit over a 3-year period, of whom 476 (42%) followed elective surgery. MAIN OUTCOME MEASURE: Hospital mortality corrected for illness severity by using the APACHE II scoring system. RESULTS: Crude hospital mortality fell from 28% before the changes to 20% afterwards ($p = 0.01$). With correction for case-mix factors, the probability of death after the changes was reduced by almost half (OR 0.51; CI 0.32, 0.82, $p = 0.005$). CONCLUSION: A "closed" format of organisation of the delivery of care may result in improved outcomes for patients admitted to intensive care units.

Effects of Tidal Volume Reduction in Acute Respiratory Distress Syndrome on Gastric Mucosal Perfusion—Sitbon P, Teboul JL, Duranteau J, Anguel N, Richard C, Samii K. Intensive Care Med 2001; 27(5):911–915.

OBJECTIVE: This study was conducted with the aim of testing the effects of a reduction in tidal volume (V_T) on gastric mucosal perfusion using laser-Doppler flowmetry in patients with acute respiratory distress syndrome (ARDS). DESIGN: It was designed as a prospective study. PATIENTS: Seventeen patients with ARDS were enrolled in the study. All patients were mechanically ventilated in volume-controlled mode. Before the start of the protocol, V_T was set at 9 mL/kg body weight. INTERVENTION: V_T was reduced to 6 mL/kg body weight. MEASUREMENTS AND RESULTS: Measurements of systemic hemodynamic parameters and gastric mucosal blood flow (GMBF) were obtained before and after reduction of V_T. Cardiac index, heaart rate and pulmonary arterial pressure increased significantly after V_T reduction. The increase in cardiac output was observed in all patients. However, despite a mean 25% increase in cardiac output after V_T reduction, no significant increase in mean GMBF was observed, and individual GMBF responses were heterogeneous. CONCLUSION: V_T reduction in patients with ARDS, despite resulting in an increase in cardiac output, did not change gastric mucosal perfusion. The heterogeneity in the individual response of GMBF to V_T reduction could be due to opposite direct (i.e., local vasodilatory effect) and indirect (i.e., global sympathetic stimulation) effects of hypercapnia on gut vessels.

Detection of Expiratory Flow Limitation by Manual Compression of the Abdominal Wall—Ninane V, Leduc D, Kafi SA, Nasser M, Houa M, Sergysels R. Am J Respir Crit Care Med 2001;163(6):1326–1330.

We have assessed a new method, manual compression of the abdominal wall (MCA) during expiration, in the detection of expiratory flow limitation. Twelve stable patients with chronic obstructive pulmonary disease (COPD) and five normal subjects were studied during spontaneous breathing in the supine and seated posture. MCA was performed during expiration with one hand at the umbilical level and we measured flow, volume, pleural (Ppl) and gastric (Pga) pressures and abdominal anteroposterior (AP) diameter at the umbilical level with magnetometers. No increase in expiratory flow during MCA relative to the preceding breath despite associated increases in pressures was considered as indicating expiratory flow limitation. In seven additional patients with increased upper airway collapsibility (obstructive sleep apnea syndrome [OSAS]), MCA was compared with negative expiratory pressure (NEP). In normal seated subjects, MCA was associated with a decrease in abdominal AP dimension (mean ± SD: -27 ± 6%), an increase in Pga (14.7 ± 7.4 cm H_2O) and Ppl (6.2 ± 2.2 cm H_2O), and an increase in expiratory flow. MCA caused similar changes in abdominal AP dimension and pressures in seated patients with COPD but six of them (50%), including four patients with FEV_1 less than 1 L, had no increase in expiratory flow. In the supine posture, MCA always increased expiratory flow in normal subjects but four additional patients with COPD showed evidence of flow limitation. MCA invariably increased expiratory flow in patients with OSAS whereas the NEP method suggested flow limitation in some cases. We conclude that MCA is a very simple method that allows detection of flow limitation in different positions.

The Association of Socioeconomic Status with Outcomes in Cystic Fibrosis Patients in the United States—Schechter MS, Shelton BJ, Margolis PA, Fitzsimmons SC. Am J Respir Crit Care Med 2001;163(6): 1331–1337.

There is considerable variability in the clinical course of disease in cystic fibrosis (CF). Although currently unidentified modifier genes might explain some of this heterogeneity, other factors are probably contributory. Socioeconomic status (SES) is an important predictor of health status in many chronic polygenic diseases, but its role in CF has not been systematically evaluated. We performed a historical cohort analysis of pediatric CF patients in the United States using National Cystic Fibrosis Foundation Patient Registry (NCFPR) data for 1986 to 1994, and used Medicaid status as a proxy for low SES. The adjusted risk of death was 3.65 times higher (95% confidence interval [CI]: 3.03 to 4.40) for Medicaid patients than for those not receiving Medicaid. The percent predicted FEV_1 of surviving Medicaid patients was less by 9.1% (95% CI: 6.9 to 11.2). Medicaid patients were 2.19 times more likely to be below the 5th percentile for weight (95% CI: 1.91 to 2.51) and 2.22 times more likely to be below the 5th percentile for height (95% CI: 1.95 to 2.52) than were non-Medicaid patients. Medicaid patients were 1.60 times more likely to require treatment for a pulmonary exacerbation (95% CI: 1.29 to 1.98). There was no difference in the number of outpatient clinic visits for Medicaid and non-Medicaid patients. We conclude that low SES is associated with significantly poorer outcomes in children with CF. Barriers in access to specialty health care do not seem to explain this difference. Further study is indicated to determine what adverse environmental factors might cluster in CF patients of low SES to cause worse outcomes.

Effect of Imposed Inflation Time on Respiratory Frequency and Hyperinflation in Patients with Chronic Obstructive Pulmonary Disease—Laghi F, Segal J, Choe WK, Tobin MJ. Am J Respir Crit Care Med 2001;163(6):1365–1370.

Decreases in ventilator inflation time (TI_{vent}) can cause tachypnea, probably as a response to lung inflation. The response may differ in chronic obstructive pulmonary disease (COPD) because time-constant inhomogeneities could foster overdistention of some lung units during early

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inflation, causing neural inspiratory time to be shorter than in healthy subjects. We tested the hypothesis that a decrease in TI_{vent} causes tachypnea, prolongation of exhalation, and a decrease in intrinsic positive end-expiratory pressure ($PEEP_i$). Ten patients with stable COPD received assist-control ventilation through a mouthpiece. Decreases in TI_{vent}, achieved through increases in flow from 30 to 90 L/min, increased frequency, from 16.1 ± 1.0 (SE) to 20.8 ± 1.5 breaths/min ($p < 0.001$), time for exhalation, from 2.1 ± 0.2 to 2.3 ± 0.2 s ($p < 0.025$), and decreased $PEEP_i$, from 7.0 ± 1.3 to 6.4 ± 1.1 cm H_2O ($p < 0.01$). Decreases in TI_{vent}, achieved by decreasing inspiratory pause from 2 to 0 s, increased frequency, from 12.9 ± 0.8 to 18.1 ± 1.6 breaths/min ($p < 0.001$), time for exhalation, from 2.0 ± 0.2 to 2.6 ± 0.3 s ($p < 0.001$), and decreased $PEEP_i$, from 6.4 ± 1.1 to 5.5 ± 0.9 cm H_2O ($p < 0.01$). In both experiments, decreases in TI_{vent} reduced inspiratory effort ($p < 0.01$). In conclusion, strategies to reduce TI,vent in patients with COPD caused tachypnea, yet prolonged the time for exhalation with consequent decrease in $PEEP_i$.

Alveolar Fluid Clearance Is Impaired in the Majority of Patients with Acute Lung Injury and the Acute Respiratory Distress Syndrome—Ware LB, Matthay MA. Am J Respir Crit Care Med 2001; 163(6):1376–1383.

Because experimental studies have shown that intact alveolar epithelial fluid transport function is critical for resolution of pulmonary edema and acute lung injury, we measured net alveolar fluid clearance in 79 patients with acute lung injury or the acute respiratory distress syndrome. Pulmonary edema fluid and plasma were sampled serially in the first 4 hours after intubation. Net alveolar fluid clearance was calculated from sequential edema fluid protein measurements. Mean alveolar fluid clearance was 6%/h. Of the patients, 56% had impaired alveolar fluid clearance (< 3%/h), 32% had submaximal clearance (≥ 3%/h, < 14%/h), and 13% had maximal clearance (≥14%/h). These findings are contrasted to our recent report of 65 patients with hydrostatic pulmonary edema, in whom mean alveolar fluid clearance was 13%/h; only 25% had impaired clearance whereas 75% had submaximal or maximal clearance (J Appl Physiol 1999;87:1301–1312). Acute lung injury with maximal alveolar fluid clearance were more likely to be female ($p = 0.03$), and less likely to have sepsis ($p = 0.01$). Endogenous and exogenous catecholamines did not correlate with alveolar fluid clearance. Patients with maximal alveolar fluid clearance had significantly lower mortality and a shorter duration of mechanical ventilation. In summary, in contrast to hydrostatic pulmonary edema, alveolar fluid clearance in patients with acute lung injury and the acute respiratory distress syndrome is impaired in the majority of patients, and maximal alveolar fluid clearance is associated with better clinical outcomes.

Quality-Adjusted Survival in the First Year After the Acute Respiratory Distress Syndrome—Angus DC, Musthafa AA, Clermont G, Griffin MF, Linde-Zwirble WT, Dremsizov TT, Pinsky MR. Am J Respir Crit Care Med 2001;163(6):1389–1394.

There is little information on long-term outcome after acute respiratory distress syndrome (ARDS). We measured quality-adjusted survival in the first year after ARDS in a prospective cohort (n = 200). All patients met traditional criteria for ARDS. Patients with sepsis and acute nonpulmonary organ dysfunction at presentation were excluded. The cohort was healthy before onset of ARDS as evidenced by high functional status (mean Karnofsky Performance Status index: 82.2/100 where ≥ 80 = able to perform normal activities independently) and minimal comorbid illness (mean Charlson-Deyo comorbidity score: 0.32/17 where 0 = absence of chronic illness). We determined quality-adjusted life-years (QALYs) using the Quality of Well-being (QWB) scale (0 to 1 scale where 1 = optimal well-being), measured at 6 and 12 mo. Survival was 69.5 ± 5.0% at 1 month, fell to 55.7 ± 3.7% at 6 mo, and did not change at 12 mo, yielding a survival of 59 life-years in the first year per 100 patients with ARDS. QWB was low at 6 and 12 mo (0.59 ± 0.015 and 0.60 ± 0.015), yielding a quality-adjusted survival of 36 QALYs per 100 patients (sensitivity range: 21 to 46 QALYs). We conclude that ARDS developing in previously healthy patients is associated with poor quality-adjusted survival. These data are important for cost-effectiveness analyses and long-term care.

Inspiratory Capacity, Dynamic Hyperinflation, Breathlessness, and Exercise Performance During the 6-Minute-Walk Test in Chronic Obstructive Pulmonary Disease—Marin JM, Carrizo SJ, Gascon M, Sanchez A, Gallego B, Celli BR. Am J Respir Crit Care Med 2001; 163(6):1395–1399.

Patients with severe chronic obstructive pulmonary disease (COPD) develop dynamic lung hyperinflation (DH) during symptom-limited incremental and constant work exercise with cycle ergometer and treadmill. The increase in end-expiratory lung volume seems to be the best predictor of dyspnea. Quantification of DH is based on the relatively complex use of on-line measurement of inspiratory capacity (IC) from flow volume loops. We reasoned that DH could occur during daily activities such as walking, and that it could be simply measured using the spirometrically determined IC. We studied 72 men with COPD (FEV_1 = 45 ± 13.3% predicted). IC was measured at rest and after a 6-min walk test. Exertional dyspnea was evaluated using the Borg scale and dyspnea during daily activities with the modified Medical Research Council (MRC) scale. IC decreased significantly from 28.9 ± 6.7% TLC at rest to 24.1 ± 6.8% TLC after exercise ($p < 0.001$). Exertional dyspnea correlated with ΔIC ($r = -0.49$, $p < 0.00001$) and baseline MRC ($r = 0.59$, $p < 0.00001$). In many patients with COPD, walking leads to DH that can be easily determined with simple spirometric testing. DH helps explain exercise capacity limitation and breathlessness during simple daily activities.

Evaluation of Two Different Educational Interventions for Adult Patients Consulting with an Acute Asthma Exacerbation—Cote J, Bowie DM, Robichaud P, Parent JG, Battisti L, Boulet LP. Am J Respir Crit Care Med 2001;163(6):1415–1419.

Asthma education decreases the number of emergency visits in specific subgroups of patients with asthma. However, it remains unknown whether this improvement is related only to the use of an action plan alone or to other components of the educational intervention. A total of 126 patients consulting urgently for an acute asthma exacerbation were recruited; 98 completed the study. The first 45 patients were assigned to Group C (control; usual treatment). Thereafter, patients were randomized to either Group LE (limited education; teaching of the inhaler technique plus self-action plan given by the on call physician) or Group SE (same as group LE plus a structured educational program emphasizing self-capacity to manage asthma exacerbations). At baseline, there was no difference between groups in asthma morbidity, medication needs, or pulmonary function. After 12 mo, only Group SE showed a significant improvement in knowledge, willingness to adjust medications, quality of life scores, and peak expiratory flows. In the last 6 mo, the number of unscheduled medical visits for asthma was significantly lower in Group SE in comparison with groups C and LE ($p = 0.03$). The number (%) of patients with unscheduled medical visits also decreased significantly in Group SE compared with Groups C and LE ($p = 0.02$). We conclude that a structured educational intervention emphasizing self-management improves patient outcomes significantly more than a limited intervention or conventional treatment.

Computed Tomography Assessment of Positive End-Expiratory Pressure-Induced Alveolar Recruitment in Patients with Acute Respiratory Distress Syndrome—Malbouisson LM, Muller JC, Constantin JM,

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Lu Q, Puybasset L, Rouby JJ; CT Scan ARDS Study Group. Am J Respir Crit Care Med 2001;163(6):1444–1450.

Computed tomography (CT) assessment of positive end-expiratory pressure (PEEP)-induced alveolar recruitment is classically achieved by quantifying the decrease in nonaerated lung parenchyma on a single juxtadiaphragmatic section (Gattinoni's method). This approach ignores the alveolar recruitment occurring in poorly aerated lung areas and may not reflect the alveolar recruitment of the entire lung. This study describes a new CT method in which PEEP-induced alveolar recruitment is computed as the volume of gas penetrating in poorly and nonaerated lung regions following PEEP. In 16 patients with acute respiratory distress syndrome a thoracic spiral CT scan was performed in ZEEP and PEEP 15 cm H_2O. According to the new method, PEEP induced a 119% increase in functional residual capacity (FRC). PEEP-induced alveolar recruitment was 499 ± 279 mL whereas distension and overdistension of previously aerated lung areas were 395 ± 382 mL and 28 ± 6 mL, respectively. The alveolar recruitment according to Gattinoni's method was 26 ± 24 g and no correlation was found between both methods. A significant correlation was found between PEEP-induced alveolar recruitment and increase in P_{aO_2} only when recruitment was assessed by the new method (Rho = 0.76, p = 0.003), suggesting that it may be more accurate than Gattinoni's method.

A Randomized, Controlled Study of a Mandibular Advancement Splint for Obstructive Sleep Apnea—Mehta A, Qian J, Petocz P, Darendeliler MA, Cistulli PA. Am J Respir Crit Care Med 2001;163(6):1457–1461.

Although there is increasing interest in the use of oral appliances to treat obstructive sleep apnea (OSA), the evidence base for this is weak. Furthermore, the precise mechanisms of action are uncertain. We aimed to systematically investigate the efficacy of a novel mandibular advancement splint (MAS) in patients with OSA. The sample consisted of 28 patients with proven OSA. A randomized, controlled three-period (ABB/BAA) crossover study design was used. After an acclimatization period, patients underwent three polysomnographs with either a control oral plate, which did not advance the mandible (A), or MAS (B), 1 wk apart, in either the ABB or BAA sequence. Complete response (CR) was defined as a resolution of symptoms and a reduction in Apnea/Hypopnea Index (AHI) to < 5/h, and partial response (PR) as a ≥ 50% reduction in AHI, but remaining ≥ 5/h. Twenty-four patients (19 men, 5 women) completed the protocol. Subjective improvements with the MAS were reported by the majority of patients (96%). There were significant improvements in AHI (30 ± 2/h versus 14 ± 2/h, $p < 0.0001$), $MinSa_{O2}$ (87 ± 1% versus 91 ± 1%, $p < 0.0001$), and arousal index (41 ± 2/h versus 27 ± 2/h, $p < 0.0001$) with MAS, compared with the control. The control plate had no significant effect on AHI and Min Sa_{O2}. CR (n = 9) or PR (n = 6) was achieved in 62.5% of patients. The MAS is an effective treatment in some patients with OSA, including those patients with moderate or severe OSA.

Safety and Reproducibility of Sputum Induction in Asthmatic Subjects in a Multicenter Study—Fahy JV, Boushey HA, Lazarus SC, Mauger EA, Cherniack RM, Chinchilli VM, et al. Am J Respir Crit Care Med 2001;163(6):1470–1475.

The safety of sputum induction and the reproducibility of measurements in induced sputum in multicenter studies is unknown. We examined the safety of sputum induction in a two-visit, six-center study in 79 subjects with moderate to severe asthma (mean ± SD FEV_1 71 ± 12% predicted, 67% taking inhaled corticosteroids). In addition, we compared the reproducibility of markers of inflammation in induced sputum with the reproducibility of the FEV_1 and the methacholine PC_{20}. The FEV_1 de-

creased ≥ 20% from the postbronchodilator baseline in 14% of all subjects and in 25% of subjects whose initial prebronchodilator baseline was 40 to 60% of predicted. All subjects responded promptly to additional albuterol treatment, and no subject developed refractory bronchoconstriction requiring treatment other than reversal of bronchospasm in the study laboratory. The reproducibility of measurements of the eosinophil percentage, eosinophil cationic protein, tryptase, and methacholine PC_{20} were similar (concordance correlation coefficients of 0.74, 0.81, 0.79, and 0.74, respectively), without any significant among-center effect. We conclude that sputum induction can be performed safely in subjects with moderate to severe asthma in multicenter clinical trials when carried out under carefully monitored conditions. Importantly, we demonstrate that measurement of markers of inflammation in induced sputum is as reproducible as methacholine PC_{20} and should prove useful in the assessment of airway inflammation in multicenter clinical trials.

Dose Dependent Increased Mortality Risk in COPD Patients Treated with Oral Glucocorticoids—Schols AM, Wesseling G, Kester AD, de Vries G, Mostert R, Slangen J, Wouters EF. Eur Respir J 2001;17(3): 337–342.

Systemic corticosteroids are often administered in COPD patients. The relationship between systemic glucocorticoids and mortality in patients with moderate to severe chronic obstructive pulmonary disease (COPD) was retrospectively analysed. Baseline characteristics of the patients, in stable clinical condition, were collected on admission to a pulmonary rehabilitation centre. Overall mortality was asessed at the end of follow-up. The Cox proportional hazards model was used to quantify the relationship between glucocorticoid use, distinguishing administration route (oral/inhalation) and oral dose, and overall mortality, adjusted for the influence of age, sex, smoking, lung function, resting arterial blood gases and body mass index. On multivariate analysis, oral glucocorticoid use at a (prednisone equivalent) dose of 10 mg × day $^{-1}$ without inhaled glucocorticoids, was associated with an increased risk (RR=2.34, 95% confidence interval (CI) 1.24–4.44) while 15 mg × day $^{-1}$ carried a relative risk of 4.03, CI = 1.99–8.15). A significant interaction was observed between inhaled and oral glucocorticoid use. Combined with inhaled glucocorticoids, the relative risk of oral glucocorticoid use appeared to be significantly smaller. It is concluded that in severe chronic obstructive pulmonary disease, maintenance treatment with oral glucocorticoids is associated with increased mortality in a dose-dependent manner. Since the present study design cannot exclude the possibility of bias by indication, further prospective studies are indicated using a broader patient characterization.

Audit of Acute Admissions of COPD: Standards of Care and Management in the Hospital Setting. Audit Sub-Committee of the Standards of Care Committee of the British Thoracic Society and the Clinical Effectiveness and Evaluation Unit at the Royal College of Physicians—Roberts CM, Ryland I, Lowe D, Kelly Y, Bucknall CE, Pearson MG. Eur Respir J 2001;17(3):343–349.

Despite publication of several management guidelines for COPD, relatively little is known about standards of care in clinical practice. Data were collected on the management of 1400 cases of acute admission with Chronic Obstructive Pulmonary Disease in 38 UK hospitals to compare clinical practice against the recommended British Thoracic Society standards. Variation in the process of care between the different centres was analysed and a comparison of the management by respiratory specialists and nonrespiratory specialists made. There were large variations between centres for many of the variables studied. A forced expiratory volume in one second measurement was found in only 53% of cases. Of the investigations recommended in the acute management arterial blood gases were performed in 79% (interhospital range 40–100%) of admissions and oxygen was formally prescribed in only 64% (range 9–94%). Of those cases with acidosis and hypercapnia 35% had no further blood gas analysis and only 13% received ventilatory support. Long-term management was also deficient with 246 cases known to be severely hypoxic on admission yet two-thirds had no confirmation that oxygen levels had returned to levels above the requirements for long-term oxygen therapy. Only 30% of current smokers had cessation advice documented. To conclude, the median standards of care observed fell below those recommended by the guidelines. The lowest levels of performance were for patients not under the respiratory specialists, but specialists also have room for improvement. The substantial variation in the process of care between hospitals is strong evidence that it is possible for other centres with poorer performance to improve their levels of care.

Utility of Echocardiography in Assessment of Pulmonary Hypertension Secondary to COPD—Higham MA, Dawson D, Joshi J, Nihoyannopoulos P, Morrell NW. Eur Respir J 2001;17(3):350–355.

Studies have confirmed the close correlation of echocardiographically estimated pulmonary arterial pressure with invasive measurements in patients with chronic obstructive pulmonary disease (COPD), but there are few data on utility of echocardiographic measurement in assessing pulmonary arterial hypertension (PH) in COPD and correlation with pulmonary function tests. Presence or absence of tricuspid regurgitation (TR) was determined by Doppler echocardiography in 73 consecutive COPD patients attending a hospital outpatient clinic. Transtricuspid pressure gradient (TTPG) was calculated. PH was defined as TTPG ≥30 mmHg. Patients also underwent spirometry, forced expiratory volume in one second (FEV_1), single breath gas transfer (carbon monoxide transfer coefficient; (K_{CO}) and carbon monoxide diffusing capacity of the lung; DL_{CO}) and arterial blood gas measurement. Measurable TR was observed in 56/73 patients (77%). There were no differences between the group in which TR was observed compared to that in which it was absent, with regard to age, smoking history nor pulmonary function variables. PH was seen in 31/56 cases (55%), with good reproducibility. There were statistically significant correlations of TTPG with FEV_1 (r=-0.26, p=0.05), K_{co} (r=-0.31, p=0.04) and DL_{CO} (r = -0.42, p = 0.006) expressed as % pred. Stepwise regression analysis showed that age and K_{CO} combined provide a multivariate model for prediction of TTPG. It is concluded the presence and degree of pulmonary arterial hypertension is readily and reliably determined by echocardiography in the majority of chronic obstructive pulmonary disease patients. Pulmonary arterial hypertension is common in severe chronic obstructive pulmonary disease and transtricuspid pressure gradient correlates with spirometry and indices of gas transfer, similar to previous invasive studies. In view of the adverse effects of pulmonary arterial hypertension on morbidity and mortality routine echocardiography in patients with severe chronic obstructive pulmonary disease may be warranted.

Alpha$_1$-Antitrypsin Genotyping with Mouthwash Specimens—Stockley RA, Campbell EJ. Eur Respir J 2001;17(3):356–359.

Alpha$_1$-antitrypsin (alpha$_1$-AT) deficiency is diagnosed as a two-stage procedure (concentration and phenotype). However the latter does not provide clues to the presence of null genes without family studies and obtaining blood from patients at a distance often proves difficult. The aim of the study was to assess the feasibility of genotyping alpha$_1$-AT using buccal cells. Mouthwash specimens were sent by 84 patients (with a variety of phenotypes of alpha$_1$-antitrypsin) through the post. Deoxyribonucleic acid (DNA) was isolated from buccal cells in each sample and subjected to polymerase chain reaction (PCR) using a genotyping kit to detect the S and Z alleles. Eighty-three of 84 samples received were suitable for amplification. The specific primers successfully identified the S and Z alleles in each case. However, five of the 35 samples obtained from patients thought to be Z allele homozygotes were found to be heterozygotes for another severe deficiency allele. These data confirm

the feasibility of "at distance" testing for alpha$_1$-antitrypsin deficiency alleles using buccal cells from mouthwash samples. The results raise the possibility that other deficiency alleles are more common than has previously been suspected.

Inhaled Corticosteroid Therapy Reduces the Risk of Rehospitalization and All-Cause Mortality in Elderly Asthmatics—Sin DD, Tu JV. Eur Respir J 2001;17(3):380–385.

Elderly patients with asthma have relatively high rates of hospitalization and mortality. Although inhaled corticosteroids have been shown to improve outcomes among younger patients with asthma, their usefulness in elderly patients has not been established. Therefore, a population-based study of patients 65 yrs of age or older, who have been hospitalized at least once with asthma in Ontario, Canada was conducted to determine the impact of inhaled corticosteroids on rehospitalization for asthma and all-cause mortality rates. Data from the Canadian Institute of Health Information was used to capture all patients 65 yrs of age and older who were hospitalized at least once, with the most responsible diagnosis of asthma in Ontario, Canada between fiscal year 1992 and 1996. This database was then linked with drug claims, physician billing and mortality databases. In total, 6,254 consecutive elderly patients with asthma were identified. Sixty percent of these patients were given at least one prescription for inhaled corticosteroids within 90 days postdischarge from their index hospitalization for asthma. Users of inhaled corticosteroids postdischarge were 29% (95% confidence interval (CI) 20%–38%) less likely to be readmitted to hospital for asthma and 39% (95% CI, 20%–53%) less likely to experience all-cause mortality compared to those who did not receive these drugs postdischarge over a one year follow-up period. These findings suggest that inhaled corticosteroids are beneficial in reducing the risk for rehospitalization and all-cause mortality in elderly patients with asthma who have recently been hospitalized for their disease.

Benefit from the Inclusion of Self-Treatment Guidelines to a Self-Management Programme for Adults with Asthma—Klein JJ, van der Palen J, Uil SM, Zielhuis GA, Seydel ER, van Herwaarden CL. Eur Respir J 2001;17(3):386–394.

This study assessed the long-term efficacy of adding self-treatment guidelines to a self-management programme for adults with asthma. In this prospective randomized controlled trial, 245 patients with stable, moderate to severe asthma were included. They were randomized into a self-treatment group (group S) and a control group (group C). Both groups received self-management education. Additionally, group S received self-treatment guidelines based on peak expiratory flow (PEF) and symptoms. Outcome parameters included: asthma symptoms, quality of life, pulmonary function, and exacerbation rate. The 2-yr study was completed by 174 patients. Both groups showed an improvement in the quality of life of 7%. PEF variability decreased by 32% and 29%, and the number of outpatient visits by 25% and 18% in groups S and C, respectively. No significant differences in these parameters were found between the two groups. After 1 yr, patients in both groups perceived better control of asthma and had more self-confidence regarding their asthma. The latter improvements were significantly greater in group S as compared to group C. There were no other differences in outcome parameters between the groups. Individual self-treatment guidelines for exacerbations on top of a general self-management programme does not seem to be of additional benefit in terms of improvements in the clinical outcome of asthma. However, patients in the self-treatment group had better scores in subjective outcome measures such as perceived control of asthma and self-confidence than patients in the control group.

Higher Occurrence of Asthma-Related Symptoms in an Urban than a Suburban Area in Adults, but Not in Children—Wieringa MH, Vermeire PA, Van Bever HP, Nelen VJ, Weyler JJ. Eur Respir J 2001, 17(3):422–427.

In young adults, a higher occurrence of asthma-related symptoms was found in an urban than an adjacent suburban area in a survey performed in 1991. The authors now wondered whether such differences could be established in other age groups. The present study (in 1996) included 14,299 subjects, aged 5–75 yrs, of a random sample of the general population in the same two adjacent areas: the centre of Antwerp (Belgium) and its south suburban border. The standardized European Community Respiratory Health Survey (ECRHS) and International Study of Asthma and Allergies in Childhood (ISAAC) questionnaires were used to assess the occurrence of asthma-related symptoms. Higher rates were confirmed in urban compared to suburban Antwerp in adults (20–75 yrs), but no such area differences were found in children (5–8 and 12–15 yrs). Adjustment for a number of recorded risk factors did not seem to affect the area differences in asthma-related symptoms. Comparing the survey results of 1991 and 1996 in 20–44 yr old adults, the findings suggest a slight increase in reported respiratory symptoms in both areas. A higher occurrence of asthma symptoms was observed in the urban than suburban area in adults, but not in children. This might be explained by a progressive effect of long-term exposure to the "urban environment." However, longitudinal studies are necessary to further clarify the factors accounting for these age-related area differences.

Ultrafine Particles in Urban Air and Respiratory Health Among Adult Asthmatics—Penttinen P, Timonen KL, Tiittanen P, Mirme A, Ruuskanen J, Pekkanen J. Eur Respir J 2001;17(3):428–435.

Airborne particles are associated with adverse health effects and contribute to excess mortality in epidemiological studies. A recent hypothesis proposes that the high numbers of ultrafine (<0.1 microm diameter) particles in ambient air might provoke alveolar inflammation and subsequently cause exacerbations in pre-existing cardiopulmonary diseases. To test the hypothesis adult asthmatics were followed with daily peak expiratory flow (PEF) measurements and symptom and medication diaries for six months, while simultaneously monitoring particulate pollution in ambient air. The associations between daily health endpoints of 57 asthmatics and indicators of air pollution were examined by multivariate regression models. Daily mean number concentration of particles, but not particle mass (PM10 (particle mass <10 microm), PM2.5–10, PM2.5, PM1), was negatively associated with daily PEF deviations. The strongest effects were seen for particles in the ultrafine range. However, the effect of ultrafine particles could not definitely be separated from other traffic generated pollutants, namely nitric oxide, nitrogen dioxide and carbon monoxide. No associations were observed with respiratory symptoms or medication use. Particle mass measurements can be strongly influenced by mechanically produced, soil-derived particles, which may not be associated with adverse health effects. Therefore, air quality monitoring should include particle number concentrations, which mainly reflect ultrafine particles.

Assessment of Passive Respiratory Mechanics in Infants: Double Versus Single Occlusion?—Goetz I, Hoo AF, Lum S, Stocks J. Eur Respir J 2001;17(3):449–455.

The single breath or occlusion technique (SOT) is widely used to assess passive respiratory mechanics in infants, but depends on various underlying assumptions. Recently, it has been proposed that such measurements could be internally validated by performing two brief airway occlusions during the same expiration. The aim of this study was to evaluate the use of the double occlusion technique (DOT) using a new commercially available program (Jaeger MasterScreen BabyBody Erich Jaeger GmbH, Wurzburg, Germany). Paired measurements of respiratory system compliance (Crs) and resistance (Rrs) using both SOT and DOT

were obtained in 18 healthy sedated infants (age range 4–41 weeks, weight 2.7–9.9 kg). There was close agreement between both methods of assessing Crs in all infants, the mean within-subject difference (95% confidence interval (CI)) for DOT-SOT being -0.06 (-0.55- +0.42) mL × kPa^{-1} × kg^{-1}. By contrast, estimates of Rrs,DO were on average 20% lower than those for Rrs,SO, (mean within-subject difference (95% CI) being -0.67 (-1.04- -0.31) kPa × L^{-1} × s; $p<0.01$). The relatively lower values obtained for Rrs,DO may reflect the higher mean lung volume at which it was calculated. Further work is required to investigate the clinical and epidemiological relevance of this new approach, and whether there are any advantages of using both techniques when assessing passive mechanics in infants.

Evaluation of a Simplified Oscillation Technique for Assessing Airway Obstruction in Sleep Apnoea—Farre R, Rigau J, Montserrat JM, Ballester E, Navajas D. Eur Respir J 2001;17(3):456–461.

The forced oscillation technique (FOT) is a noninvasive method that is useful for assessing airway obstruction and for titrating continuous positive airway pressure (CPAP) in patients with sleep apnoea. The aim was to evaluate the routine applicability of a simplified FOT set-up based on recording pressure and flow at the level of the CPAP device, i.e. obviating the need for connecting the transducers to the nasal mask. A correction to account for the tubing and the exhaust port was applied. This simplified FOT was evaluated on nine patients with moderate or severe sleep apnoea during routine CPAP titration. Patient impedance measured by the simplified FOT ([Z]) was compared with actual patient impedance ([Zrs]) measured simultaneously with a reference FOT based on recording pressure and flow at the nasal mask. An excellent agreement was found between [Z] and [Zrs] over the wide range of airway obstruction explored (4.8–72.1 $cmH_2O \times s \times L^{-1}$): $[Z] = [Zrs] \times 0.86 + 1.3$ $cmH_2O \times s \times L^{-1}$ ($r = 0.99$). Moreover, the simplified and the conventional FOT settings detected the same respiratory events during sleep. These results demonstrate that this simplified FOT is applicable for measuring airway obstruction during routine sleep studies in patients with sleep apnoea.

Long-Term Use of Mandibular Advancement Splints for Snoring and Obstructive Sleep Apnoea: A Questionnaire Survey—McGown AD, Makker HK, Battagel JM, L'Estrange PR, Grant HR, Spiro SG. Eur Respir J 2001;17(3):462–466.

A mandibular advancement splint (MAS) may be an alternative treatment for snoring and obstructive sleep apnoea (OSA). However, there is little subjective or objective information concerning long-term effectiveness, compliance and side effects. A retrospective questionnaire was used to survey these issues plus patient satisfaction and maintenance requirements in 166 patients who could have worn a mandibular advancement splint for over a year. One-hundred and twenty-six (76%) subjects returned the questionnaire, (84 with OSA, 42 snorers), of whom 69 (55%) reported still using the splint regularly, 47 (37%) every night. The most common reported reasons for stopping use were discomfort (29/ 57; 52%) of nonusers), and poor perceived efficacy (12 subjects). Users reported more daytime symptoms, and they and their partners were more likely to observe improvements with splint use. Side effects were reported by 49 subjects, more commonly in nonusers. Sixty-five of 67 current users and 23 of 41 nonusers reported less snoring with splint use ($p = < 0.001$). Long-term mandibular advancement splint usage appeared less satisfactory than previously reported, however, splints were considered effective by 97% of current users and even by over half of those who had stopped use. Reasons for stopping use included side effects, social circumstances, dental treatment, as well as lack of perceived efficacy.

Proportional Positive Airway Pressure: A New Concept to Treat Obstructive Sleep Apnoea—Juhasz J, Becker H, Cassel W, Rostig S, Peter JH. Eur Respir J 2001;17(3):467–473.

Proportional positive airway pressure (PPAP) was designed to optimize airway pressure for the therapy of obstructive sleep apnoea (OSA). In a randomized crossover prospective study, the clinical feasibility of PPAP and its immediate effects on the breathing disorder and sleep in comparison with continuous positive airway pressure (CPAP) was evaluated. Twelve patients requiring CPAP therapy underwent CPAP and PPAP titration in a random order. Obstructive and mixed respiratory events could be completely abolished with both forms of treatment. This efficacy could be achieved at a significantly lower mean mask pressure during PPAP titration (8.45±2.42 cm H_2O) compared to CPAP (9.96±2.7 cm H_2O) ($p=0.002$). The mean minimal arterial oxygen saturation (S_{aO_2}) (82.8±6.5%) on the diagnostic night increased significantly ($p<0.001$) to an average S_{aO_2} of 93.35±1.71% and 93.19±2.9% during CPAP and PPAP titration. Total sleep time, slow wave sleep and rapid eye movement (REM) sleep increased significantly by the same amount during both CPAP and PPAP titration ($p<0.001$), while sleep stage nonrapid eye movement (NREM) 1 and 2 decreased. Six patients preferred the PPAP titration night, four patients did not have a preference, and two patients preferred CPAP. The present data show that proportional positive airway pressure is as effective as continuous positive airway pressure in eliminating obstructive events and has the same immediate effect on sleep. The lower average mask pressure during proportional positive airway pressure implies potential advantages compared to continuous positive airway pressure. Proportional positive airway pressure presents a new effective therapeutic approach to obstructive sleep apnoea.

Airway Resistance Measured by the Interrupter Technique: Expiration or Inspiration, Mean or Median? Bridge PD, McKenzie SA. Eur Respir J 2001;17(3):495–498.

The measurement of airway resistance by the interrupter technique (Rint) needs standardization. Should measurements be made be during the expiratory or inspiratory phase of tidal breathing? In reported studies, the measurement of Rint has been calculated as the median or mean of a small number of values, is there an important difference? Subjects were 2.5–5.0 yrs (median 4.0 yrs) who had previous respiratory symptoms. The Rint in expiration (RintE) and inspiration (RintI) pre and postsalbutamol, the coefficient of variation (CV) of values contributing to measurements, and bronchodilator responsiveness(BDR) in both phases were compared. Measurements using median and mean were compared. RintE was higher than RintI by 4% ($p < 0.01$). The CV of values making up RintE and RintI, and BDR measured in expiration and inspiration were similar. The median difference between means and medians of values making up measurements was 0.6% (range -6–11%). RintE has been shown to be consistently greater then RintI but the difference in this study is small. It is suggested that one or the other is chosen as the standard. In the present data the mean of a set of values contributing to a measurement was not significantly different from the median. However, the use of the median has been recommended since it is less affected by possible outlying values such as might be included by fully automated equipment.

New Anti-Asthma Therapies: Suppression of the Effect of Interleukin (IL)-4 and IL-5—Kips JC, Tournoy KG, Pauwels RA. Eur Respir J 2001;17(3):499–506.

Asthma is currently defined as a chronic inflammatory disorder of the airways. The central role of allergen-specific Th2 cells in the regulation of this mucosal airway inflammation has been highlighted. Hence, there is large interest in the therapeutic potential of an anti-Th2 cell approach. One of the strategies which has been developed, is to inhibit the effect of interleukin (IL)-4 or IL-5, two main Th2 cell derived cytokines. Inter-

leukin-4 is pivotal in the pathogenesis of allergic disorders through its wide range of effects. An important observation, especially during secondary antigen exposure, is the possible redundancy with IL-13. Both cytokines share common elements in their receptor and intracellular signalling pathway. As a result, compounds can be developed that selectively inhibit the effect of either IL-4 or IL-13, or alternatively, by interfering with the common pathway, inhibit the effect of both cytokines. Eosinophils are generally seen as a particularly harmful element in the allergic inflammation. The importance of IL-5 on eosinophil biology has clearly been established. Conversely, in man, the biological effects of IL-5 are largely limited to eosinophil function. Therefore, IL-5 antagonists offer the unique opportunity of selectively neutralizing the effect of eosinophils. Several strategies have now been developed that successfully inhibit the biological effect of interleukin-4 or interleukin-5. Some of these compounds have proven to be biologically active in man. The challenge now is to establish their therapeutic role in asthma.

Imaging Guided Thoracic Interventions—Ghaye B, Dondelinger RF. Eur Respir J 2001;17(3):507–528.

Interventional Radiology is a technique based medical specialty, using all available imaging modalities (fluoroscopy, ultrasound, computed tomography, magnetic resonance, angiography) for guidance of interventional techniques for diagnostic or therapeutic purposes. Actual, percutaneous transthoracic needle biopsy includes core needle biopsy besides fine needle aspiration. Any pleural, pulmonary or mediastinal fluid or gas collection is amenable to percutaneous pulmonary catheter drainage. Treatment of haemoptysis of the bronchial artery or pulmonary artery origin, transcatheter embolization of pulmonary arteriovenous malformations and pseudoaneurysms, angioplasty and stenting of the superior vena caval system and percutaneous foreign body retrieval are well established routine procedures, precluding unnecessary surgery. These techniques are safe and effective in experienced hands. Computed tomography is helpful in pre- and postoperative imaging of patients being considered for endobronchial stenting. Many procedures can be performed on an outpatient basis, thus increasing the cost-effectiveness of radiologically guided interventions in the thorax.

The Bias Flow Nitrogen Washout Technique for Measuring the Functional Residual Capacity in Infants. ERS/ATS Task Force on Standards for Infant Respiratory Function Testing—Morris MG, Gustafsson P, Tepper R, Gappa M, Stocks J. Eur Respir J 2001;17(3):529–536.

The functional residual capacity (FRC) is the most commonly measured static lung volume in infants. It is important for interpreting volume-dependent pulmonary mechanics, e.g. airway resistance, and defining normal lung growth. The bias flow nitrogen washout technique is widely used for measuring FRC because the dead space and circuit resistance are low, making it suitable for small or sick infants. Moreover, data acquisition and calculation are easily programmed for a personal computer. The aim of this paper is to provide recommendations pertaining to equipment requirements, study procedures and reporting of data for functional residual capacity measurements. While measuring the functional residual capacity is regarded as physiologically and clinically important, the accuracy of the measurement is undoubtedly equally important. Hence, the paper also emphasizes factors influencing the accuracy of functional residual capacity measurements independent of equipment requirements. These recommendations represent the "State of the Art" in 2000.

High-Flow Nasal Cannulae in the Management of Apnea of Prematurity: A Comparison with Conventional Nasal Continuous Positive Airway Pressure—Sreenan C, Lemke RP, Hudson-Mason A, Osiovich H. Pediatrics 2001;107(5):1081–1083.

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Apnea of prematurity (AOP) is frequently managed with nasal continuous positive airway pressure (NCPAP). Nasal cannula (NC) are used at low flows (<0.5 L/min) to deliver supplemental oxygen to neonates. A number of centers use high-flow nasal cannula (HFNC) in the management of AOP without measuring the positive distending pressure (PDP) generated. Objective. To determine the NC flow required to generate PDP equal to that provided by NCPAP at 6 cm H_2O and to assess the effectiveness of HFNC as compared NCPAP in the management of AOP. Method. Forty premature infants, gestation 28.7 ± 0.4 weeks (mean ± standard error of mean), postconceptual age at study 30.3 ± 0.6 weeks, birth weight 1256 ± 66 g, study weight 1260 ± 63 g who were being managed with conventional NCPAP for at least 24 hours for clinically significant apnea of prematurity, were enrolled in a trial of ventilator-generated conventional NCPAP versus infant NC at flows of up to 2.5 L/min. End expiratory esophageal pressure was measured on NCPAP and on NC, and the gas flow on NC was adjusted to generate an end expiratory esophageal pressure equal to that measured on NCPAP. Two 6-hour periods were continuously recorded and the data were stored on computer. Results. The flow required to generate a comparable PDP with NC varied with the infant's weight and was represented by the equation: flow (L/min) = 0.92 + 0.68x, x = weight in kg, R = 0.72. There was no difference in the frequency and duration of apnea, bradycardia or desaturation per recording between the 2 systems. Conclusion. NC at flows of 1 to 2.5 L/min can deliver PDP in premature neonates. HFNC is as effective as NCPAP in the management of AOP.

Closed-Loop Controlled Inspired Oxygen Concentration for Mechanically Ventilated Very Low Birth Weight Infants with Frequent Episodes of Hypoxemia—Claure N, Gerhardt T, Everett R, Musante G, Herrera C, Bancalari E. Pediatrics 2001;107(5):1120–1124.

Background. Mechanically ventilated very low birth weight infants often present with frequent episodes of hypoxemia, and maintaining arterial oxygen saturation by pulse oximetry (S_{pO_2}) within a normal range by manual fraction of inspired oxygen (F_{IO_2}) adjustments is difficult and time consuming. Objectives. An algorithm for closed-loop F_{IO_2} control (cF_{IO_2}) to maintain S_{pO_2} within a target range was compared with continuous manual F_{IO_2} (mF_{IO_2}) adjustments by a nurse in a group of ventilated infants who presented with frequent episodes of hypoxemia. Results. Fourteen infants (birth weight: 712 ± 142 g; gestational age: 25 ± 1.6 weeks; age: 26 ± 11 days; synchronized intermittent mandatory ventilation rate: 24 ± 10 b/m; peak inspiratory pressure: 17.5 ± 2.0 cm H_2O; positive end-expiratory pressure: 4.3 ± 0.5 cm H_2O) were studied for 2 hours on each mode in random sequence. Both modes aimed to maintain S_{pO_2} between 88% and 96%. There were 15 ± 7 and 16 ± 6 hypoxemic episodes/hour (S_{pO_2} <88%, >5 s) during mF_{IO_2} and cF_{IO_2}, respectively; episode duration was 41 ± 23 and 32 ± 15 s, totaling 19 ± 16% and 17 ± 12% of recording time. There were 13 ± 10 and 10 ± 8 hyperoxemic episodes/hour (S_{pO_2}>96%, >5 s) during mF_{IO_2} and cF_{IO_2} respectively; episode duration was 27 ± 15 and 24 ± 19 s, totaling 15 ± 14% and 10 ± 9% of recording time. Mean S_{pO_2} and F_{IO_2} levels were similar during both modes. The nurse made 29 ± 17 adjustments/hour during mF_{IO_2}. There was a significant increase in the duration of normoxemia (S_{pO_2} between 88%–96%) during cF_{IO_2} (75 ± 13 vs 66 ± 14% of recording time). Conclusion. In this group of infants, cF_{IO_2} was at least as effective as a fully dedicated nurse in maintaining S_{pO_2} within the target range, and it may be more effective than a nurse working under routine conditions. We speculate that during long-term use, cF_{IO_2} may save nursing time and reduce the risks of morbidity associated with supplemental oxygen and episodes of hypo- and hyperoxemia.

Antibiotic Prescribing Practices in a Teaching Clinic: Comparison of Resident and Staff Physicians—Mincey BA, Parkulo MA. South Med J 2001;94(4):365–369.

BACKGROUND: The widespread and often inappropriate use of broad spectrum antibiotics in the outpatient setting is recognized as a significant contributing factor to the spread of bacterial resistance. We hypothesized that residents prescribe broader spectrum antibiotics more frequently than staff physicians and adopt more appropriate prescribing practices with increasing levels of training. METHODS: All patient visits for acute sinusitis in our teaching practice between July 1, 1995, and June 30, 1997, were reviewed. Comparisons of antibiotics prescribed were made between staff and residents at each level of training. RESULTS: First- and second-year residents were more likely to prescribe narrow spectrum antibiotics (56%) than third-year residents (35%) or staff (34%). CONCLUSIONS: Junior residents in our program are more likely to prescribe narrow spectrum antibiotics for the treatment of acute sinusitis than are senior residents or staff. With advancement in level of training, prescribing practices of residents come to resemble those of their supervising staff physicians.

A Comparison of Tracheal Tube Tip Designs on the Passage of an Endotracheal Tube During Oral Fiberoptic Intubation—Greer JR, Smith SP, Strang T. Anesthesiology 2001;94(5):729–731; discussion 5A.

BACKGROUND: The design of an endotracheal tube has been shown to influence the passage of the tube through the glottis during fiberoptic intubation. Difficulty in passing the endotracheal tube can occur if the aryepiglottic folds obstruct the passage of the bevel. The relevant aspects of endotracheal tube design include the shape of the bevel, the material used by the manufacturer, and the ability of the tube to conform to the shape of the fiberscope. The aim of the current study was to compare the ease of passage through the glottis of two different tubes. One tube was a wire reinforced polyvinyl chloride tube with a standard bevel and the other was a newly designed tube with a bevel of different shape and made of silicone rubber. The new design is for use with the a commerical intubating laryngeal mask. METHODS: The authors studied a population of 30 patients who received a standard anesthetic. In all cases, oral fiberoptic intubation was attempted. Anesthetic was administered to each patient using both tubes, and before the study the order of the tubes was randomized. The difficulty in passing the tube was assessed by a blinded observer and graded using a three-point scale (grade 1: no difficulty passing the tube; grade 2: obstruction to passing the tube relieved by withdrawal and a 90 degrees anticlockwise rotation; grade 3: obstruction necessitating more than one manipulation or external laryngeal manipulation). RESULTS: In 27 patients, no difficulty was shown by use of the silicone-tipped tube. In only three patients was there difficulty that necessitated a 90 degrees anticlockwise twist. With the wire-reinforced tube, no difficulty was experienced on 14 occasions. Grade 1 difficulty was experienced eight times and difficulty necessitating more than one maneuver, head movement, or external laryngeal manipulation was seen on eight occasions. Statistical significance was achieved at $p = 0.0002$ (Wilcoxon signed rank test). CONCLUSIONS: The authors conclude that the use of the silicone-tipped tube with the new bevel design may provide an advantage in the clinical situation of fiberoptic intubation.

Pharyngolaryngeal Morbidity with the Laryngeal Mask Airway in Spontaneously Breathing Patients: Does Size Matter?—Grady DM, McHardy F, Wong J, Jin F, Tong D, Chung F. Anesthesiology 2001; 94(5):760–766.

BACKGROUND: Currently, the manufacturer of the laryngeal mask airway (LMA; Laryngeal Mask Company, Ltd., Northfield End, Henley on Thames, Oxon, United Kingdom) recommends using as large a mask size as possible. The aim of this study was to compare the incidence of pharyngolaryngeal morbidity after the use of a large (size 5 in males and size 4 in females) or small (size 4 in males and size 3 in females) LMA in spontaneously breathing patients. METHODS: A total of 258 male and female patients were randomly assigned to insertion of a large or small LMA while breathing spontaneously during general anesthesia. After insertion of the LMA, a "just-seal" cuff pressure was obtained, and intracuff pressure was measured at 10-min intervals until just before removal of the LMA. The 2- and 24-h incidence of postoperative sore throat, pain, hoarseness, dysphagia, and nausea and vomiting was assessed. Complications after LMA removal, including body movement, coughing, retching, regurgitation, vomiting, biting on the LMA, bronchospasm, laryngospasm, or the presence of blood on the LMA, were recorded. RESULTS: The use of a large LMA was associated with a higher incidence of sore throat in both sexes (20% vs. 7% in men, 21% vs. 5% in women; $p < 0.05$) and a higher incidence of hoarseness in male patients at 2 h postoperatively (21% vs. 9%, $p < 0.05$). There was a higher incidence of sore throat in male patients at 24 h postoperatively with the use of a large LMA (26% vs. 12%, $p < 0.05$). There was no difference in the incidence of complications of LMA removal orother pharyngolaryngeal morbidity, such as difficulty swallowing, drinking, and eating, or nausea and vomiting, between male or female groups at any time period with the use of a large LMA. CONCLUSIONS: Selection of a small laryngeal mask airway (size 4) in spontaneously breathing male patients may be more appropriate to limit the occurrence of sore throat on the first postoperative day. All patients had a fourfold increased risk of developing sore throat when a large LMA was used.

Optimal Mean Airway Pressure During High-Frequency Oscillation: Predicted by the Pressure-Volume Curve—Goddon S, Fujino Y, Hiromi JM, Kacmarek RM. Anesthesiology 2001;94(5):862–869.

BACKGROUND: A number of groups have recommended setting positive end-expiratory pressure during conventional mechanical ventilation in adults at 2 cm H_2O above the lower corner pressure (P_{CL}) of the inspiratory pressure-volume (P-V) curve of the respiratory system. No

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equivalent recommendations for the setting of the mean airway pressure ($\bar{P}_{aw}$) during high-frequency oscillation (HFO) exist. The authors questioned if the $\bar{P}_{aw}$ resulting in the best oxygenation without hemodynamic compromise during HFO is related to the static P-V curve in a large animal model of acute respiratory distress syndrome. METHODS: Saline lung lavage was performed in seven sheep (28±5 kg, mean ± SD) until the arterial oxygen partial pressure/fraction of inspired oxygen ratio decreased to 85±27 mm Hg at a positive end-expiratory pressure of 5 cm H_2O (initial injury). The P_{CL} (20±1 cm H_2O) on the inflation limb and the point of maximum curvature change (PMC; 26±1 cm H_2O) on the deflation limb of the static P-V curve were determined. The sheep were subjected to four 1-h cycles of HFO at different levels of $\bar{P}_{aw}$ (P_{CL} + 2, + 6, + 10, + 14 cm H_2O), applied in random order. Each cycle was preceded by a recruitment maneuver at a sustained $\bar{P}_{aw}$ of 50 cm H_2O for 60 s. RESULTS: High-frequency oscillation with a $\bar{P}_{aw}$ of 6 cm H_2O above P_{CL} (P_{CL} + 6) resulted in a significant improvement in oxygenation ($p < 0.01$ vs. initial injury). No further improvement in oxygenation was observed with higher $\bar{P}_{aw}$, but cardiac output decreased, pulmonary vascular resistance increased, and oxygen delivery decreased at $\bar{P}_{aw}$ greater than P_{CL} + 6. The PMC on the deflation limb of the P-V curve was equal to the P_{CL} + 6 ($r = 0.77$, $p < 0.05$). CONCLUSION: In this model of acute respiratory distress syndrome, optimal $\bar{P}_{aw}$ during HFO is equal to P_{CL} + 6, which correlates with the PMC.

Comparison of the Intubating Laryngeal Mask Airway with the Fiberoptic Intubation in Anticipated Difficult Airway Management—Langeron O, Semjen F, Bourgain J-L, Marsac A, Cros A-M. Anesthesiology 2001;94:968–972.

Background: The intubating laryngeal mask airway (ILMA; Fastrach; Laryngeal Mask Company, Henley-on-Thames, UK) may provide an alternative technique to fiberoptic intubation (FIB) to facilitate the management of the anticipated difficult airway. The authors therefore compared the effectiveness of the ILMA with FIB in patients with anticipated difficult intubation. Methods: One hundred patients, with at least one difficult intubation criteria (Mallampati class III or IV, thyromental distance < 65 mm, interincisor distance < 35 mm) were enrolled (FIB group, n = 49; ILMA group, n = 51) in this prospective randomized study. Anesthesia was induced with propofol and maintained with alfentanil and propofol after an efficient mask ventilation has been demonstrated. The success of the technique (within three attempts), the number of attempts, duration of the successful attempt, and adverse events (oxygen saturation < 90%, bleeding) were recorded. Results: The rate of successful tracheal intubation with ILMA was 94% and comparable with FIB (92%). The number of attempts and the time to succeed were not significantly different between groups. In case of failure of the first technique, the alternative technique always succeeded. Failures in FIB group were related to oxygen desaturation (oxygen saturation < 90%) and bleeding, and to previous cervical radiotherapy in the ILMA group. Adverse events occurred significantly more frequently in FIB group than in ILMA group (18 vs. 0%, $p < 0.05$). Conclusion: The authors obtained a high success rate and comparable duration of tracheal intubation with ILMA and FIB techniques. In patients with previous cervical radiotherapy, the use of ILMA cannot be recommended. Nevertheless, the use of the ILMA was associated with fewer adverse events.

Neonatal Pulmonary Hypertension: Urea-Cycle Intermediates, Nitric Oxide Production, and Carbamoyl-Phosphate Synthetase Function—Pearson DL, Dawling S, Walsh WF, Haines JL, Christman BW, Bazyk A, et al. N Engl J Med 2001;344(24):1832–1838.

BACKGROUND: Endogenous production of nitric oxide is vital for the decrease in pulmonary vascular resistance that normally occurs after birth. The precursor of nitric oxide is arginine, a urea-cycle intermediate. We hypothesized that low concentrations of arginine would correlate with the presence of persistent pulmonary hypertension in newborns and that the supply of this precursor would be affected by a functional polymorphism (the substitution of asparagine for threonine at position 1405 [T1405N]) in carbamoyl-phosphate synthetase, which controls the rate-limiting step of the urea cycle. METHODS: Plasma concentrations of amino acids and genotypes of the carbamoyl-phosphate synthetase variants were determined in 65 near-term neonates with respiratory distress. Plasma nitric oxide metabolites were measured in a subgroup of 10 patients. The results in infants with pulmonary hypertension, as assessed by echocardiography, were compared with those in infants without pulmonary hypertension. The frequencies of the carbamoyl-phosphate synthetase genotypes in the study population were assessed for Hardy-Weinberg equilibrium. RESULTS: As compared with infants without pulmonary hypertension, infants with pulmonary hypertension had lower mean (±SD) plasma concentrations of arginine (20.2±8.8 vs. 39.8±17.0 micromol per liter, $p<0.001$) and nitric oxide metabolites (18.8±12.7 vs. 47.2±11.2 micromol per liter, $p=0.05$). As compared with the general population, the infants in the study had a significantly skewed distribution of the genotypes for the carbamoyl-phosphate synthetase variants at position 1405 ($p<0.005$). None of the infants with pulmonary hypertension were homozygous for the T1405N polymorphism. CONCLUSIONS: Infants with persistent pulmonary hypertension have low plasma concentrations of arginine and nitric oxide metabolites. The simultaneous presence of diminished concentrations of precursors and breakdown products suggests that inadequate production of nitric oxide is involved in the pathogenesis of neonatal pulmonary hypertension. Our preliminary observations suggest that the genetically predetermined capacity of the urea cycle—in particular, the efficiency of carbamoyl-phosphate synthetase—may contribute to the availability of precursors for nitric oxide synthesis.

Reduction in Colonization and Nosocomial Infection by Multiresistant Bacteria in a Neonatal Unit after Institution of Educational Measures and Restriction in the Use of Cephalosporins—Calil R, Marba ST, Von Nowakonski A, Tresoldi AT. Am J Infect Control 2001; 29(3):133–138.

INTRODUCTION: Previous administration of third-generation cephalosporins predisposes to colonization and infections by multiresistant Enterobacter sp. The emergence of multiresistant bacteria infections in a neonatal unit during 1995, especially *Enterobacter cloacae*, stimulated this study. OBJECTIVE: To evaluate the efficacy of measures to control colonization and nosocomial infection by multiresistant bacteria in a neonatal unit. SETTING: A tertiary care university hospital. Patients and Methods: This study was conducted from October 1995 through December 1999 in 4 phases: a cross-sectional study, a longitudinal study with intervention measures, monthly cross-sectional studies, and determination of nosocomial infections caused by multiresistant bacteria (oxacillin-resistant *Staphylococcus aureus* and gram-negative bacteria resistant to either aminoglycosides or third-generation cephalosporins). Specimens for surveillance culture were obtained through umbilical and rectal swabs, and tracheal aspirates from intubated babies. The intervention measures were as follows: (1) appropriated training of the whole health care team, emphasizing measures to reduce cross-colonization, and the importance of rational usage of antibiotics and (2) suppression of usage of third-generation cephalosporins. Risk factors were analyzed through univariate and multivariate logistic regression. RESULTS: In the first phase, 32% (10/31) of the patients were colonized by multiresistant bacteria (29% by multiresistant *E cloacae*). In the second phase, 342 patients were evaluated; 33% of them were colonized by *E cloacae*, and a multiresistant strain was isolated in 10.8% (37/342) of the babies. A logistic regression model indicated parenteral nutrition and antibiotic usage as risk factors for colonization by multiresistant *E cloacae*. In the third phase, for 6 months, only 2 patients were colonized by multiresistant *E cloacae*. In the fourth phase, the analysis of bacterial resistance profile indicated a reduction of nosocomial infections due to multiresistant bacteria from 18

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cases in 1995 to 2 cases per year until 1999. CONCLUSION: These results have shown that the measures adopted were effective.

Infection Control Programs at Children's Hospitals: A Description of Structures and Processes—Girouard S, Levine G, Goodrich K, Jones S, Keyserling H, Rathore M, et al. Pediatric Prevention Network. Am J Infect Control 2001;29(3):145–151.

BACKGROUND: Infection control (IC) structures and processes determine the effectiveness of surveillance efforts to prevent infections in health care settings. METHODS: A survey was sent to 56 children's hospitals collaborating in the Pediatric Prevention Network (PPN). RESULTS: Completed surveys were returned from 48 hospitals. Responsibility for the IC program resided with the medical director (21%); vice president for patient care (18%); quality improvement director (17%); other senior hospital administrator (15%); or other hospital personnel (18%). Forty-two hospitals had an IC committee; 32 had antimicrobial restriction/control policies; and 21 had an antimicrobial restriction/control task force or committee. Components of antimicrobial restriction programs included infectious disease specialist approval, restricted formularies, selective susceptibility test reporting, and staff education programs. Many methods were used to detect infections, including microbiology laboratory reports (100%); record reviews (98%); informal reports from providers (90%); and readmission reviews (77%). CONCLUSIONS: Children's hospitals vary widely in how they design and implement their IC functions. These variations influence adverse event detection and nosocomial infection rate calculations. If medical errors, including nosocomial infections, are to be detected and hospital rates compared, standardized methods to collect, analyze, and report data are needed. The PPN has initiated activities to standardize surveillance and IC practices in participating hospitals.

Nosocomial Infection Rates in US Children's Hospitals' Neonatal and Pediatric Intensive Care Units—Stover BH, Shulman ST, Bratcher DF, Brady MT, Levine GL, Jarvis WR. Pediatric Prevention Network. Am J Infect Control 2001;29(3):152–157.

BACKGROUND: Few data are available on nosocomial infections (NIs) in US children's hospitals' neonatal or pediatric intensive care units. The Pediatric Prevention Network (PPN) was established to improve characterization of NIs in pediatric patients and to develop and test interventions to decrease NI. METHODS: Fifty participating children's hospitals were surveyed in 1998 to determine NI surveillance methods used and neonatal intensive care unit (NICU) and pediatric intensive care unit (PICU) 1997 NI rates. Data were collected on standardized forms and entered and analyzed by using SPSS for Windows. RESULTS: Forty-three (86%) children's hospitals returned a completed questionnaire. All reported conducting NICU and PICU NI surveillance (range, 2–12; median, 12 months). Nineteen children's hospitals provided NICU NI rate data in one or more formats suitable for comparison. Denominators used for NICU NI rate calculations varied: 17 reported overall NI by patient-days; 19 reported bloodstream infection (BSI) by central venous catheter (CVC)-days, and 8 reported BSI by patient-days. Sixteen (16) children's hospitals reported NICU BSI data stratified by CVC-days and birthweight cohort, and ventilator-associated pneumonia (VAP) by birth weight cohort was reported by 12. Twenty-four children's hospitals reported PICU NI rate data in one or more formats suitable for comparison. Denominators used for PICU NI rate calculations also varied: 20 reported overall NI rates by patient-days; 23 reported BSI rates by CVC-days, and 10 reported BSI rates by patient-days; 24 reported VAP by ventilator-days; and 15 reported urinary tract infections (UTIs) by urinary catheter-days. Median overall NI rates per 1000 patient days were 8.9 in NICUs and 13.9 in PICUs. Median NICU NI device-associated rates by birth weight (>2500 g, 1501–2500 g, 1001–1500 g, and ≤1000 g) were BSI

4.4, 4.7, 8.9, and 12.6, and VAP 0.9, 1.1, 4.9, and 3.5, respectively. Median PICU NI rates per 1000 device days were 6.5 for BSI; 3.7 for VAP; and 5.4 for UTI. CONCLUSIONS: The number of months that NICU or PICU NI surveillance was conducted varied among hospitals. Reported NICU and PICU NI rates varied by hospital; some reported overall NI rates, and others focused on one or more particular sites of infection (eg, BSI or pneumonia). Many did not provide NICU device-associated rates stratified by birth-weight group. Denominators used to calculate device-associated infection rates also varied, with hospitals reporting either patient-days or device-days. These findings suggest the need to determine reasons for variations and to identify optimal NI surveillance methods at children's hospitals so that valid interhospital NI rate comparisons can be made.

Mechanical Ventilation in Children with Severe Asthma—Malmstrom K, Kaila M, Korhonen K, Dunder T, Nermes M, Klaukka T, et al. Pediatr Pulmonol 2001;31(6):405–411.

Hospital admissions for childhood asthma have increased during the past few decades. The aim of this study was to describe the need for mechanical ventilation for severe asthma exacerbation in children in Finland from 1976 to 1995. We reviewed medical records and collected data retrospectively from all 5 university hospitals in Finland, thus covering the entire population of about 5 million. The endpoints selected were the number of admissions and readmissions leading to mechanical ventilation, duration of stay in the hospital, and mortality. Moreover, asthma medications prescribed prior to admission and administered in the intensive care unit (ICU), as well as the etiology of the exacerbation associated with mechanical ventilation were examined. Mechanical ventilation was required in 66 ICU admissions (59 patients). This constituted approximately 10% of all 632 admissions for acute asthma to an ICU. The number of admissions decreased from 1976 to 1995: 41 admissions between 1976 and 1985 vs. 25 admissions during the next 10-year period. The mean age at admission to the ICU was 3.6 years, and 46% of the patients were boys. Prior to the index admission, 70% of the patients had used asthma medication such as oral bronchodilator (50%), inhaled bronchodilator (20%), theophylline (38%), inhaled glucocorticoid (18%), oral glucocorticoid (5%), and cromoglycate (7%). Respiratory infection was by far the most common cause of all the exacerbations (61%), followed by food allergy (8%) and gastroesophageal reflux (3%). In 28% of cases the cause of the severe asthma exacerbation could not be identified. In the mechanically ventilated patients readmissions occurred 38 times between 1976 and 1985 vs. 5 times between 1986 and 1995. Five of the patients who received mechanical ventilation died, and in 3 of these patients asthma was the event causing death. In conclusion, there has been decrease in the number of first and repeat ICU admission for asthma requiring mechanical ventilation between 1970 and 1995. This trend occurred despite a simultaneous 5% yearly increase in hospital admissions for childhood asthma during these 2 decades.

Functional Residual Capacity and Passive Compliance Measurements after Antenatal Steroid Therapy in Preterm Infants—McEvoy C, Bowling S, Williamson K, Stewart M, Durand M. Pediatr Pulmonol 2001;31(6):425–430.

Studies in preterm animal models have shown that antenatal corticosteroids enhance lung maturation by improving a variety of physiologic variables, including lung volumes. Changes in lung volume of preterm infants treated with a full course of antenatal steroids have not been investigated. We hypothesized that a full course of antenatal steroids would significantly increase functional residual capacity (FRC) in treated vs. untreated preterm infants. The objective of our study was to compare FRC and respiratory mechanics in steroid treated vs. untreated preterm infants. FRC and passive respiratory mechanics were prospectively studied within 36 hr of life in 20 infants (25–34 weeks of gestation) who had received a full course of antenatal steroids and in 20 matched untreated preterm infants. FRC was measured with the nitrogen washout method, and respiratory mechanics with the single-breath occlusion technique. Preterm infants who received steroids (n = 20; mean birth weight = 1,230 g; gestational age = 28.8 weeks) had a significantly higher FRC (29.5 vs. 19.3 mL/kg; $p < 0.001$) than untreated infants (n = 20; birth weight = 1,202 g; gestational age = 28.5 weeks). Passive respiratory system compliance was also increased in treated vs. untreated infants ($p < 0.05$). In conclusion, FRC and passive respiratory system compliance were significantly improved in preterm infants (25–34 weeks gestation) treated with a full course of antenatal steroids, compared to matched untreated infants. Although this study was not randomized, it confirms that antenatal steroids have important effects on pulmonary function that may contribute to a decreased risk of respiratory distress syndrome in treated preterm infants.

Defining an Exacerbation of Pulmonary Disease in Cystic Fibrosis—Dakin C, Henry RL, Field P, Morton J. Pediatr Pulmonol 2001;31(6): 436–442.

Despite the importance of pulmonary exacerbations in CF in both clinical and research settings, both published evidence and consensus are lacking concerning the criteria used to define an exacerbation. The use of hospitalization as a surrogate measure presupposes uniformity among clinicians in diagnosis and treatment of exacerbations. Our aims were to evaluate consensus among clinicians about the variables considered helpful in diagnosing an exacerbation requiring treatment. A comprehensive list of symptoms, signs, and investigations used to define exacerbations was compiled from published trials. A written self-administered questionnaire included the list in age-appropriate groups to survey opinion about the helpfulness of each item, and the estimated proportion of patients admitted within a month of diagnosis of an exacerbation. This was sent to all clinicians managing CF patients in Australia. There were replies from 59/91 clinicians (65%), 41/60 (68%) from those managing children and 18/31 (58%) from those managing adults. Responses of those managing children and adults differed for 7/32 variables (Mann-Whitney test, $p < 0.05$). Clinic grouping did not show greater consensus among responses of pediatricians (Kruskal-Wallis test, $p = 0.362$). Consensus, >74% or <26% of respondents rating a variable helpful/very helpful, was found in only 50% of variables listed. Estimated admission rate within a month of diagnosis was 61% (30–100%) for those managing adults and 48% %5–100%) for pediatricians. A lack of consensus was found among clinicians managing CF about the variables considered in diagnosing an exacerbation. The estimated proportion admitted within a month of diagnosis was very variable. This demonstrated inhomogeneity in approach to diagnosis and management of an exacerbation suggests a significant heterogeneity of clinical care.

Transition Programs in Cystic Fibrosis Centers: Perceptions of Pediatric and Adult Program Directors—Flume PA, Anderson DL, Hardy KK, Gray S. Pediatr Pulmonol 2001;31(6):443–450.

There is a growing population of adults with cystic fibrosis (CF) and a need for development of adult CF programs. Recommendations for transfer of patients to an adult program include a transition program. Our goal was to assess the current status of transition programs in US CF centers. In addition, we sought to determine the problems related to the transfer of patients to adult programs as perceived by CF center program directors. A survey was sent in 1998 to 110 pediatric and 44 adult program directors at CF centers approved by the Cystic Fibrosis Foundation (CFF), with a response rate of 65.5% and 72.7%, respectively: 22.2% of pediatric centers reported having a non-CFF-approved adult program, and 38.9% had no specific adult program. About one fifth of pediatric centers cited lack of an adult CF physician as an impediment to establishing an adult program. Age (82% of programs; mean, 18.5 years), but not mar-

riage (17.1%) or pregnancy (24.8%), was used as a criterion for transfer. Criteria precluding transfer included patient/family resistance (51.4%), disease severity (50.5%), and developmental delay (46.7%). The concept of transfer is introduced to the patient and family at the time of diagnosis in a minority (14%) of programs. Over one half of the patients did not meet the adult team until the time of transfer. Pediatricians reported higher perceived parent, patient, pediatric staff, and adult staff concerns about transition issues than did adult program directors. We conclude that there is a lack of standardized programs for transfer of CF patients from a pediatric to an adult care setting, and that there are differences between pediatric and adult program directors' perceptions of concerns that CF patients, their families, and the medical teams have about transfer. These differences may impede the successful transition of patients into an adult program.

Reduction of Oscillatory Pressure Along the Endotracheal Tube Is Indicative for Maximal Respiratory Compliance During High-Frequency Oscillatory Ventilation: A Mathematical Model Study—van Genderingen HR, Versprille A, Leenhoven T, Markhorst DG, van Vught AJ, Heethaar RM. Pediatr Pulmonol 2001;31(6):458–463.

We hypothesized that during high-frequency oscillatory ventilation (HFOV), a reduction of peak-to-peak oscillatory pressure along the endotracheal tube is maximal when respiratory system compliance is maximal. We made a mathematical model of the endotracheal tube and the respiratory system of a neonate suffering from idiopathic respiratory distress syndrome (IRDS). The model consisted of linear viscous and inertive elements, a non-linear endotracheal tube resistance, and a non-linear compliance allowing for alveolar recruitment and overdistention. Respiratory compliance was maximal at the transition between maximal recruitment and minimal overdistention. A new variable, the oscillatory pressure ratio (OPR), was defined as the ratio between peak-to-peak oscillatory pressures at the distal end and the proximal opening of the endotracheal tube, respectively. The respiratory variables of four patients were fed into the model, and the relationship between respiratory system compliance and OPR was determined. OPR decreased as compliance increased, except for very low compliances below where 0.08 mL cm H_2O^{-1}, and OPR increased with increasing compliance. The relationship between mean airway pressure $\bar{P}_{aw}$ and OPR revealed that the minimal OPR (range, 0.37–0.78) and maximal respiratory compliance coincided at the same $\bar{P}_{aw}$. However, the relationship did depend on oscillation frequency, applied oscillatory pressure, and endotracheal tube resistance, parameters that may change during clinical application of HFOV. When 81 permutations of nominal and extreme respiratory variables were used in the model, the minimum OPR (0.60 ± 0.23) and maximum compliance coincided in all cases. These model experiments support our hypothesis. The results indicate that the OPR may be a useful index to optimize lung expansion, where lung recruitment is maximal and overdistention minimal. In vivo tests will be needed to reveal the feasibility and reliability of such an index for biomedical and clinical application.

Cigarette Smoking and the Risk of Pulmonary Metastasis from Breast Cancer—Murin S, Inciardi J. Chest 2001;119(6):1635–1640.

Study objectives: To determine whether there is an association between cigarette smoking and the development of pulmonary metastatic disease among women with breast cancer. DESIGN: A case-control study. SETTING: The University of California, Davis Medical Center. PARTICIPANTS: Eighty-seven women patients with unilateral, invasive breast cancer and pulmonary metastatic disease were identified as cases, and each patient was matched with two control patients who did not have pulmonary metastatic disease. Case patients and control patients were matched for year of diagnosis, age at diagnosis, size of primary tumor, and nodal status. Data analysis: Multivariate analysis using conditional logistic regression was used to determine the odds of smoking among women with pulmonary metastatic disease compared to matched control patients without pulmonary metastatic disease, after correction for potential confounding factors. RESULTS: Thirty-eight percent of the case patients vs 29% of the control patients were classified as ever-smokers; 24.1% of case patients were actively smoking at the time of breast cancer diagnosis vs 15.3% of the control patients. The unadjusted odds ratio for active smoking was 1.76 for women with pulmonary metastatic disease compared to women without pulmonary metastatic disease ($p = 0.06$). In the final multivariate model, the odds ratio for active smoking among women with pulmonary metastatic disease was 1.96 ($p = 0.06$). CONCLUSIONS: There appears to be an association between cigarette smoking and the development of pulmonary metastatic disease among women with breast cancer. This may explain the previously noted higher breast cancer fatality rate among smokers. The relationship between smoking behavior and pulmonary metastasis from breast and other cancers warrants further investigation.

Is It Really Useful to Repeat Outpatient Pulmonary Rehabilitation Programs in Patients with Chronic Airway Obstruction?: A 2-Year Controlled Study—Foglio K, Bianchi L, Ambrosino N, Fondazione S. Chest 2001;119(6):1696–1704.

Study objectives: To answer the following questions: in patients with chronic airway obstruction (CAO), (1) can pulmonary rehabilitation lead to similar short-term gains at successive, yearly interventions, and (2) is there any real clinical or physiologic long-term benefit by yearly repetition of pulmonary rehabilitation programs (PRPs)? DESIGN: Randomized, controlled clinical study. SETTING: Pulmonary rehabilitation center. PATIENTS: Sixty-one CAO patients studied 1 year after completing an initial 8-week outpatient PRP (PRP1). INTERVENTION: Patients were randomly classified into two groups. A second PRP (PRP2) was completed by the first group (group 1) but not by the second group (group 2). One year later, a third PRP (PRP3) was performed by both groups. MEASUREMENTS: Lung function, cycloergometry, walking test, dyspnea, and health-related quality of life (HRQL) were assessed before and after PRP2, and before and after PRP3. The numbers of hospitalizations and exacerbations over the year were also recorded. RESULTS: Complete data sets were obtained from 36 patients (17 patients in group 1 and 19 patients in group 2). The two groups did not differ in any parameter either before PRP1, after PRP1, or at randomization. There was no significant change over time for airway obstruction in either group. After PRP2, exercise tolerance, dyspnea, and HRQL improved in group 1. Nevertheless, 1 year later, patients of group 1 did not differ from patients of group 2 in any outcome parameter, such that in comparison to before PRP1, only HRQL was still better in both groups 24 months after PRP1. Yearly hospitalizations and exacerbations per patient significantly decreased in both groups in the 2 years following PRP1, when compared to the 2 years prior. Nevertheless, at the 24-month follow-up visit, a further reduction in yearly exacerbations was observed only in group 1 but not in group 2 in comparison to what was observed at the 12-month follow-up visit. The PRP3 resulted in improvement in exercise tolerance in both groups. CONCLUSION: In patients with CAO, an outpatient PRP can achieve benefits in HRQL and a decreased number of hospitalizations, which persist for a period of 2 years. Successive, yearly interventions lead to similar short-term gains but do not result in additive long-term physiologic benefits. Further reduction in yearly exacerbations seems to be the main benefit of an additional PRP.

Ventilator Circuit Changes: "Wu Wei"* May Save Time, Labor, and Money

Jean-Damien Ricard MD and Didier Dreyfuss MD

Patients undergoing mechanical ventilation are exposed to the risk of ventilator-associated pneumonia (VAP). Many studies that have addressed pharmacologic and nonpharmacologic interventions to avoid or reduce the incidence of VAP have recently been comprehensively reviewed.[1] Amongst the nonpharmacologic interventions, particular interest has grown around airway management[2] and its potential influence on VAP.[3] Frequency of ventilator circuits changes and its relation to VAP has been one of the first topics investigators have focused on.

See the Original Study on Page 891

Back in 1978, Lareau et al showed that incidence of VAP was the same whether the circuits were changed every 8 or 24 hours.[4] Several years later, Craven et al showed that increasing the duration of use of the circuits from 24 to 48 hours not only did not increase the incidence of VAP,[5] it could even decrease it.[6] The problem was finally cleared in 1991 when it was shown for the first time that VAP rate was the same whether circuits were changed every 2 days or not changed at all.[7] This important finding was later confirmed with consistent results from 2 teams in 1995.[8,9] Taken together, these studies have indisputably shown that not changing circuits does not increase the incidence of VAP. However, and despite the abundant evidence for this simple attitude, a recent international multicenter survey[10] highlighted important differences between countries in the frequency of circuit changes. In this survey, less than 20% of Canadian intensive care units (ICUs) reported changing their circuits only between patients, whereas this figure rose to 73.6% in France. It was suggested that to some extent the existence of French studies addressing this issue[7] may influence French practice patterns only. Similar findings were obtained concerning the choice of humidification, with heat and moisture exchangers being preferentially used in France, whereas heated humidifiers were used by a majority of ICUs in Canada.[10] These results stress the lack of impact of published results on clinical practice and the influence a national expertise in a given subject may exert on national practice patterns. In this respect, the paper by Han et al published in this issue of Respiratory Care may have important clinical and economic consequences. In that study, the authors examine the rate of VAP in ICU patients from 2 periods: one during which circuits were changed every 48 hours and the other where the circuit-change interval was 7 days.[11] Using a noninvasive VAP diagnostic strategy (Centers for Disease Control criteria), they found that VAP rate significantly decreased when the circuit change interval was increased from 2 to 7 days. Han et al must be commended for having performed such an important study, which included a total of 644 patients in less comfortable conditions than Western investigators are accustomed to. Indeed, in their hospital, nearly half of the patients are ventilated outside the ICU! Such a setting explains why it was difficult for them to obtain extensive and exhaustive data on the patients included in their study. The mortality rate was similar in both periods, but we are given few data on the severity of the patients' illness in the 2 groups, the reasons for mechanical ventilation, the use of antibiotics prior to the diagnosis of VAP, or the prophylaxis of stress ulcer. These are important factors that may influence VAP. Nevertheless, it remains that in that particular setting, the authors have clearly shown that, at the least, extending the interval between 2 circuit changes is safe and does not increase the risk of VAP.

As stated above, there is now no doubt that increasing the duration of use of ventilator circuits does not increase the rate of VAP. The question that remains is whether or not this practice reduces the rate of VAP.

Table 1 reports the various studies that have addressed this issue. The vast majority of these studies found no decrease in the rate of VAP with less frequent circuit change. Although studies differed considerably either in design or in the methods used to diagnose VAP, the results appear to be consistent. Only 3 of the 8 studies[4,7–9,11–14] were randomized. All 3 studies found no reduction in the rate of VAP when circuits were less frequently changed,[7–9] one of these studies having used invasive bacteriologic sampling for the diagnosis of VAP.[7] Only one study (along

* The Chinese concept of "wu wei," as explained in the report by Han et al in this issue of Respiratory Care, can be translated as "not doing."

Table 1 Effect on VAP Rate of Extending the Interval Between Ventilator Circuit Changes

Study, Year	Patients (*n*)	Study Design	VAP Diagnostic Procedure	Intervention	Result
Lareau et al, 1978[4]	484	Sequential	CDC criteria	8 vs 24 h	No difference
Dreyfuss et al, 1991[7]	63	Randomized	Lower respiratory tract sampling with quantitative cultures	2 d vs no change	No difference
Hess et al, 1995[8]	3,423	Sequential	CDC criteria	2 vs 7 d	No difference
Kollef et al, 1995[9]	300	Randomized	CDC criteria	7 d vs no change	No difference
Long et al, 1996[12]	447	Randomized	CDC criteria	2 vs 7 d	No difference
Kotilainen and Keroack, 1997[13]	146	Sequential	CDC criteria	3 vs 7 d	No difference
Fink et al, 1998[14]	637	Sequential	CDC criteria	2 vs 7 d and 30 d	Less VAP with 7 d and 30 d
Han et al, 2001[11]	644	Sequential	CDC criteria	2 vs 7 d	Less VAP with 7 d

VAP = ventilator associated pneumonia
CDC = United States Center for Disease Control.

with the present study by Han et al) reported that less frequent circuit change reduced incidence of VAP.[14] However, as acknowledged by the authors, their study was limited by the lack of a concurrent control group and the comparison of other potential risk factors for VAP (eg, pre-VAP antibiotic, antacid therapy).[14] Given these results, it seems fair to say that there are more convincing data in favor of the absence of reduction in VAP rate with less frequent change.

In the same way as extending the duration of use of heat and moisture exchangers,[15–20] one of the major advantages of less frequent circuit changes lies in the important reduction in the cost of mechanical ventilation. Lowering expenditures is obtained by 2 means: first, substantially fewer circuits are used for each patient (at the most only one is necessary per patient), and, second, staff labor is reduced. As stated above, despite the large body of evidence proving that this practice is easy to implement, safe, and cost-effective, a number of ICUs do not apply it, even more so in Canada than in France.[10] This may, in part, account for differences in the costs of mechanical ventilation that could exist between these 2 Western countries.[10] Some may argue that the cost savings that result from less frequent circuit change are minimal when compared to other expenditures such as antibiotics or antiviral therapies. Nevertheless, "il n'y a pas de petites économies" as we would say in France ("any saving is worth taking, however small it may be"), and this may be even more true in China.

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Effects of Decreasing the Frequency of Ventilator Circuit Changes to Every 7 Days on the Rate of Ventilator-Associated Pneumonia in a Beijing Hospital

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INTRODUCTION: We investigated whether decreasing ventilator circuit changes from every 2 days to every 7 days would impact ventilator-associated pneumonia rates at our institution. METHODS: All mechanically ventilated patients at Peking Union Medical College Hospital were studied over a 21 month period. From March 1998 to February 1999, ventilator circuits were changed every 2 days, and from June through December 1999, ventilator circuits were changed every 7 days. Nosocomial pneumonia was identified using the criteria of the Centers for Disease Control. RESULTS: In the 2-day-change group, there were 2,277 ventilator-patient days and 38 patients developed pneumonia, resulting in a pneumonia rate of 16.7 cases per 1,000 ventilator days. The 7-day-change group accumulated 972 ventilator days and 8 patients contracted pneumonia, resulting in a pneumonia rate of 8.2 cases per 1,000 ventilator days. The pneumonia rate was significantly lower in the 7-day-change group ($p = 0.007$). To standardize for seasonal variability, we compared results from the same seasonal time frames (June to December 1998 for the 2-day-change group, and June to December 1999 for the 7-day-change group), and obtained similar findings: during those periods, pneumonia rates were 24.2 cases per 1,000 ventilator days for the 2-day-change group and 8.9 cases per 1,000 ventilator days for the 7-day-change group ($p = 0.001$). CONCLUSIONS: A circuit change interval of 7 days had a lower risk of ventilator-associated pneumonia than a 2-day change interval. Therefore, ventilator circuits can be safely changed every 7 days in our setting. *Key words: nosocomial pneumonia, mechanical ventilation, respiratory therapy, ventilator circuit change, China.* [Respir Care 2001;46(9):891–896]

Introduction

Daily changing of ventilator circuitry had been a standard practice based on outbreaks of nosocomial pneumonia in the 1960s.[1] The described cases of pneumonia were associated with contaminated nebulizer reservoirs that delivered aerosolized bacteria directly to patients' airways and lungs. Since most current mechanical ventilators use humidifiers that produce molecular water, the aerosolized transmission of bacteria would not seem to pose an important risk of pneumonia in ventilated patients.[1] The risk factors for pneumonia in patients receiving mechanical ventilation were systematically studied by Craven et al,[2–4] who reported that when substantial bacterial colonization was present in the respiratory tubing, there was no significant increase in airway colonization after 48 hours, compared to 24 hours of continuous ventilation.[2] They found that circuit colonization originates primarily from the pa-

See the Related Editorial on Page 888

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tient's secretions and that contaminated condensate may collect in the ventilator circuit, increasing the risk of ventilator-associated pneumonia (VAP).[3] The possibility of spillage of condensate into the airways was supported by a later study indicating that changing ventilator circuits every 24 hours rather than every 48 hours increased the risk of pneumonia, presumably by increasing manipulation of the circuitry, with consequent translocation of contaminated condensate into the patient's airway.[4]

In 1991 Dreyfuss et al[5] investigated the association between ventilator circuit change frequency and pneumonia, finding that the incidence of pneumonia was not significantly higher when the circuits were never changed, compared to circuit change every 48 hours. They concluded that substantial savings in disposable tubing costs and personnel time could be realized by reducing circuit change frequency, without an increase in the rate of pneumonia.[5] Based on such observations, the United States Centers for Disease Control (CDC) altered their guidelines for prevention of nosocomial pneumonia to state that "daily change in ventilator circuits may be extended to ≥ 48 hours. . . . The maximum time, however, that a circuit can be safely left unchanged on a patient has yet to be determined."[6]

More recent research in acute and subacute care settings has suggested that extending the interval between ventilator circuit changes beyond 2 days (7, 14, or 30 d, or no change) does not increase the incidence of nosocomial pneumonia and may even reduce it.[7–10] Significant cost savings was a consistent finding from those extended-interval studies.[8–12]

Unlike the majority of United States hospitals, Chinese hospitals do not have respiratory care practitioners to standardize ventilator management. We wondered whether the aforementioned reports were valid in our institution. To what extent does the practice of reducing circuit change frequency, developed primarily in Western hospitals and in non-Asian populations, apply to Chinese patients in our setting? To address this question, we conducted the present study at Peking Union Medical College Hospital to compare VAP rates associated with circuit changes of every 2 days versus every 7 days.

Methods

Patient Selection

The patients were recruited at Peking Union Medical College Hospital, a 1,000-bed facility with 500 patients receiving mechanical ventilation per year in the pulmonary intensive care unit (ICU), surgical ICU, coronary care unit, emergency department, and other critical care areas throughout the hospital. Data related to all ventilated patients were collected on a standardized form and transferred to the database in our respiratory care center. From the collective database we determined the number of patients receiving mechanical ventilation, the number developing pneumonia, the number of ventilator days elapsing prior to a diagnosis of pneumonia, accumulated days of mechanical ventilation, and mortality in ventilated patients. Patients who were not intubated (ie, were ventilated noninvasively) were not included in the study.

During a 21-month period, all patients receiving invasive mechanical ventilation were concurrently evaluated by two of the authors (DML and JNH) to identify the presence of VAP, using the 1988 CDC criteria.[13] The 2-day circuit change group consisted of 413 patients receiving mechanical ventilation during a 12-month period from March 1998 to February 1999. From March to May 1999 a circuit change interval of 7 days was gradually instituted. During this period 122 other patients were reviewed, but the data were not included in the analysis because in some units the circuits were changed every 2 days and in the others every 7 days. The 7-day-change group had 231 patients evaluated from June 1999 to December 1999.

The study design was approved by the Infection Control Committee of Peking Union Medical College Hospital. Except for the frequency of ventilator circuit changes, the care of patients was not otherwise affected by the present study. There were no important changes in antibiotic use or nutritional support during the study period.

Diagnosis of Ventilator-Associated Pneumonia

The CDC criteria for nosocomial pneumonia include various combinations of clinical, radiographic, and laboratory evidence of infection. The diagnosis of pneumonia must meet one of 2 conditions:

1. Rales or dullness to percussion on physical examination of chest, new onset of purulent sputum or change in character of sputum, a pathogen isolated by blood culture, and/or isolation of a pathogen from a specimen obtained by transtracheal aspirate or bronchial lavage, or

2. New or progressive infiltrate, consolidation, cavitation, or pleural effusion on chest radiographic examination, new onset of purulent sputum or change in character of sputum, or organism isolated from blood culture and/or isolation of pathogen from specimen obtained by transtracheal aspirate or bronchial lavage.[13]

A nosocomial pneumonia was considered ventilator-associated if it occurred ≥ 24 hours after the initiation of mechanical ventilation or within 48 hours after ventilator disconnection, unless the patient had a witnessed aspiration within the first 24 hours of initiation of the ventilator.[12] In the event of unsuccessful weaning (ie, ventilatory support required < 48 hours after weaning), the patient was kept in the study until permanent discontinuation of mechanical ventilation. The mortality

analysis included any studied patient who died during hospitalization.

Equipment and Ventilation Technique

Patients were mechanically ventilated with either a Servo 900C or Servo 300 (Siemens-Elema, Solna, Sweden) equipped with a wick-type humidifier (MR730, Fisher & Paykel, Auckland, New Zealand). The inspiratory limb of the ventilator circuit had a heated wire to reduce the formation of condensate and thereby eliminate the need for a water trap in the inspiratory limb. The expiratory limb had a water trap midway between the ventilator and the patient (to collect tubing condensate), and the trap was emptied when a substantial amount of condensate collected. The inspiratory limb provided a gas temperature of 33–36° C at the proximal end of the endotracheal tube. The humidifier reservoir was periodically refilled with sterile water, using aseptic technique. The ventilator circuits (including swivel adaptor, Y-piece, inspiratory and expiratory tubing, heated wire, water trap, and humidifier reservoir) were reusable and sterilized between patients. A disposable open suctioning system was used with all patients. Aerosol therapy during mechanical ventilation was not routinely delivered and was limited to patients with obstructive airway disease. Nasogastric tubes were placed in patients who needed gastric suction or enteral feeding.

Circuit Change Practices

Ventilator circuits were changed at the predetermined intervals. In addition, ventilator circuits were changed, in part or whole, when the circuit was visibly soiled or there was a suspected mechanical malfunction of the circuitry.

Statistical Analysis

The variables assessed in both groups of patients are expressed as mean for age and median for the duration of mechanical ventilation. Comparisons between the 2 patient groups were by Student's *t* test for age and chi-square test for pneumonia and mortality rates. The Wilcoxon 2-sample test was used to compare the duration of mechanical ventilation. Differences with $p < 0.05$ were considered statistically significant.

Results

A total of 644 patients were included: 413 patients in the 2-day-change group and 231 patients in the 7-day-change group. The groups did not differ in terms of age or total duration of mechanical ventilation, except that the 2-day-change group had a slightly higher proportion of female patients (38% vs 30%, $p = 0.04$) (Table 1).

Table 1 Patient Characteristics

	Group		p
	2-Day*	7-Day*	
Number of Patients	413	231	
Age (y)	52.1	54.1	0.22
Duration of MV (d)	11	11	0.50
Cases of pneumonia	38	8	0.007
Duration of MV prior to pneumonia (d)	14	32	0.40

*Ventilator circuit change interval (every 2 days or every 7 days).
MV = mechanical ventilation.

In the 2-day-change group there were 2,277 ventilator days, and 38 of those patients developed pneumonia, resulting in a pneumonia rate of 16.7 cases per 1,000 ventilator days. The 7-day-change group accumulated 972 ventilator days, and 8 of those patients contracted pneumonia, for a pneumonia rate of 8.2 cases per 1,000 ventilator days. The pneumonia rate was significantly lower in the 7-day-change group ($p = 0.007$).

When patients ventilated for ≤ 2 days were excluded from the analysis, similar results were obtained: the pneumonia rate was 19.0 cases per 1,000 ventilator days in the 2-day-change group (37 cases of pneumonia and 1,946 ventilator days), versus 10.2 cases per 1,000 ventilator days in the 7-day-change group (7 cases of pneumonia and 784 ventilator days). That difference in pneumonia rate was, again, significant ($p = 0.006$).

Table 1 lists the incidence and timing of onset of pneumonia after initiating mechanical ventilation. Ventilator-associated pneumonia occurred at a median of 14 days after initiation of mechanical ventilation in the 2-day-change group, and 32 days after initiation of mechanical ventilation in the 7-day-change group. The difference was not significant ($p = 0.40$).

In the 2-day-change group, 116 patients (28.2%) and in the 7-day-change group 71 patients (30.7%) died during hospitalization. The difference was not significant ($p = 0.49$). As illustrated in Figure 1, mortality appeared to be higher in patients with pneumonia (42.1% in the 2-day-change group versus 50.0% in the 7-day-change group).

To determine possible effects of seasonal variation between the 2 groups, pneumonia rates were calculated for patients ventilated during the same seasonal time frame (June through December 1998 for the 2-day-change group, and June through December 1999 for the 7-day-change group). In those seasonal sub-groups there were 241 patients in the 2-day-change group and 229 patients in the 7-day-change group. In the 2-day-change group there were 1,155 ventilator days, and 28 of those patients developed pneumonia. The 7-day-change group accumulated 895 ventilator days, and 8 of those patients contracted pneumonia.

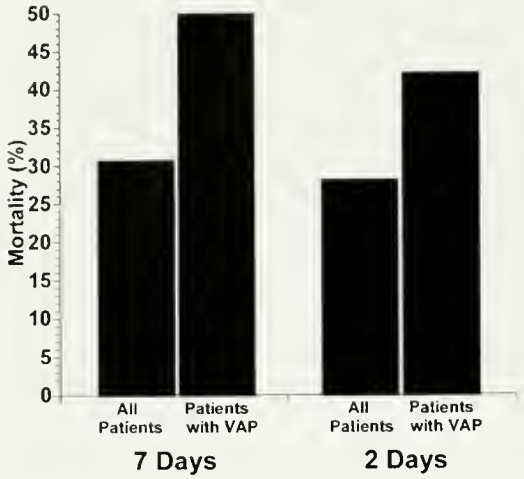

Fig. 1. Mortality of patients receiving mechanical ventilation and of patients with ventilator-associated pneumonia (VAP) with circuit change intervals of 2 days and 7 days. Note that there was no difference in mortality between the 2-day-change and 7-day-change groups, and note the tendency for higher mortality in patients with pneumonia.

Similar results were obtained: a pneumonia rate of 24.2 cases per 1,000 ventilator days in the 2-day-change group and 8.9 cases per 1,000 ventilator days in the 7-day-change group ($p = 0.001$). The mortality rates were not different (24.6% in the 2-day-change group and 31.0% in the 7-day-change group, $p = 0.12$).

Discussion

Ventilator-associated pneumonia is one of the most common nosocomial infections and is associated with increased mortality and duration and cost of hospitalization.[14,15] Such consequences justify efforts to reduce its incidence. Although ventilator circuit changes have been performed to reduce the risk of VAP, the value of increasing ventilator circuit change frequency has been questioned in systematic evaluations over the past 2 decades. We presumed that if the results of previous studies that dissociate the circuit change frequency and VAP rate can be validated in our specific setting, the morbidity and costs associated with the care of ventilated patients could be substantially reduced.

Over the past 15 years, ICUs have been gradually established in our hospital, including pulmonary ICU, coronary care unit, and surgical ICU. However, compared to hospitals in the West, we have relatively few ICUs, and nearly half of the ventilated patients receive mechanical ventilation outside of an ICU, in critical care beds throughout our hospital (44% of the patients in the present study). Doctors and nurses share the task of respiratory care for ventilated patients.

In this study we found that extending the ventilator circuit change interval to 7 days significantly reduced the incidence of pneumonia, compared with a 2-day circuit change interval. No statistical differences in mortality were found between the 2 groups, although patients with pneumonia tended to have higher mortality. This finding extends the work of Craven et al,[4] who found that the rate of pneumonia was 2.3 times higher in patients who had ventilator circuits changed every 24 hours than in those who had their circuits changed every 48 hours.

Inadvertent flushing of contaminated condensate into the patient's airway and increased manipulation of the patient's airway while applying manual resuscitation bag ventilation during the ventilator circuit change may be important contributors to infection. As the manual resuscitation bag is attached to the airway during the circuit change, leakage might occur around the cuff, allowing secretions to enter the airway.

Our results are consistent with other recently published studies[8,12,16,17] finding that extending the circuit change interval from 2 days to 7 days reduced the rate of pneumonia (Fig. 2).

The patients with VAP in the present study were identified primarily by the CDC clinical criteria.[13] Clinical criteria to establish the diagnosis of VAP might not be as accurate as those based on lower respiratory tract sampling.[5] Because of its invasive nature, the lower respiratory tract sampling method could not be applied to the relatively large number of patients in the present study. However, studies using a strict diagnosis of pneumonia (including invasive sampling technique and quantitative cultures)[5-7] have yielded similar outcome incidence as those using usual clinical diagnostic methods[8,12] to explore the circuit change frequency question.

With a traditional ventilator circuit, the rate of condensate formation has been estimated to be 30 mL/h,[3] resulting from the temperature drop between the humidifier and the proximal end of the endotracheal tube. The heated wire circuits used in this study maintained the temperature of the gas en route from the humidifier to the patient, eliminating the formation of condensate. Accordingly, heated wire circuits reduce the risk of inadvertent lavage of the patient's airway with contaminated condensate.

A higher rate of VAP was found in the present study than in the study by Fink et al,[12] who reported an incidence of 6.3 cases per 1,000 ventilator days over a 30-day circuit change interval. Our results are consistent with those of Dreyfuss et al,[7] who found a pneumonia incidence of 9.14 cases per 1,000 ventilator days with no circuit changes. The reasons for the differences are unclear. A different proportion of surgical versus medical patients, or differences in facility flora, infection control practices, or tube change practices might account for the different pneumonia rates.

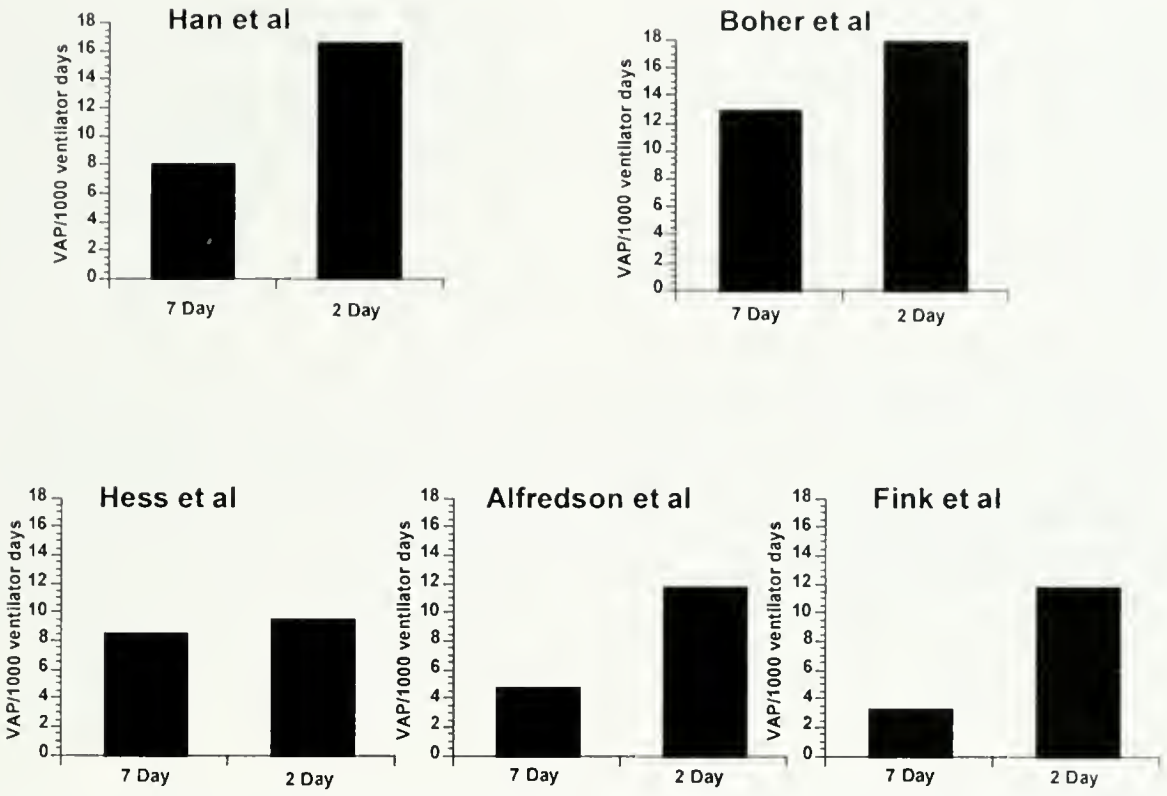

Fig. 2. Comparison of the present study to previously published studies on the incidence of ventilator-associated pneumonia (VAP) with circuit change frequencies of 2 days and 7 days. VAP rates are per 1,000 ventilator days. (Adapted from Boher et al,[17] Hess et al,[8] Alfredson et al,[16] and Fink et al.[12])

There is a known seasonal variation in the incidence of nosocomial pneumonia. Craven et al[4] found a 2-fold increase in pneumonia during the fall and winter seasons. The design of the present study could have selected the same time periods for study on consecutive years. Yet, when patients ventilated in the same seasonal time frame were compared, similar results were obtained, with higher pneumonia rates in the 2-day-change group than the 7-day-change group.

A potential limitation of the present study was the sequential design, with the 2-day-change study period preceding the 7-day-change study period, which might not adequately control for systematic changes in practice over the entire study period. A randomized design would have avoided this potential problem with our findings. However, we do not believe that this factor was sufficiently important to affect our findings, since there were no changes in other relevant factors throughout the study period. From 1998 to 2000 there were no important changes in mechanical ventilation strategy, the use of antacids or H_2 receptor inhibitors for gastrointestinal bleeding, or infection control policies for patients receiving mechanical ventilation in our hospital.

Conclusions

In conclusion, we found a lower incidence of VAP among patients receiving circuit changes every 7 days than in those receiving circuit changes every 2 days. Therefore, we conclude that ventilator circuits can be safely changed every 7 days in our setting. The story of ventilator circuit changes thus might be best rendered by the traditional Chinese concept of "Wu Wei," linguistically translated as "not doing," but in this case more specifically as "not overdoing or not interfering."

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The Fraction of Inspired Oxygen in Infants Receiving Oxygen via Nasal Cannula Often Exceeds Safe Levels

John W Kuluz MD, Gwenn E McLaughlin MD, Barry Gelman MD, G Patricia Cantwell MD, James Thomas RRT, Thomas Mahon RRT, and Charles L Schleien MD

OBJECTIVE: Measure the fraction of inspired oxygen (F_{IO_2}) in infants receiving supplemental oxygen via nasal cannula and identify clinical variables that affect F_{IO_2}. METHODS: Hypopharyngeal gas samples were obtained from 20 infants receiving oxygen via nasal cannula at flows between 0 and 4 L/min. F_{IO_2} was calculated using the alveolar gas equation and measurements of partial pressure of oxygen in the samples and the barometric pressure. RESULTS: F_{IO_2} increased as oxygen flow was increased. F_{IO_2} exceeded safe levels (> 60%) in two thirds of samples when the oxygen flow was 2 L/min or higher. Tachypnea (respiratory rate > 40 breaths/min) was associated with lower F_{IO_2}. CONCLUSION: Infants receiving oxygen via nasal cannula at ≥ 2 L/min may be at risk for hyperoxic lung injury. Therefore, we recommend using the lowest possible oxygen flow needed to maintain normoxia in infants requiring prolonged oxygen therapy via nasal cannula. *Key words: respiratory therapy, lung injury, free radicals, oxygen toxicity, hyperoxia, respiratory failure, pediatrics.* [Respir Care 2001;46(9):897–901]

Introduction

The nasal cannula is frequently used to deliver oxygen to unintubated infants and children. Its advantages over other oxygen delivery systems include low cost, light weight, flexibility, patient comfort, and the ease with which it is secured to the face and kept in position.[1–4] Although several studies have documented the fraction of inspired oxygen (F_{IO_2}) at various oxygen flows from nasal cannulae in adults,[5–10] little is known about the efficiency of this oxygen delivery system in infants and children or about the clinical factors that might affect F_{IO_2}. The purpose of this study was to measure F_{IO_2} in infants receiving oxygen via nasal cannula at flows of up to 4 L/min and to identify clinical variables that affect F_{IO_2}. Because of the small tidal volumes and low inspiratory flows of infants, we hypothesized that the F_{IO_2} in infants receiving oxygen via nasal cannula is higher than that delivered to adults.

Methods

This study was approved by the Institutional Review Board of the University of Miami School of Medicine. Informed consent was obtained from a parent or legal guardian prior to patient enrollment. Infants receiving oxygen via nasal cannula in the pediatric intensive care unit were eligible for the study. A total of 20 patients were studied.

Hypopharyngeal F_{IO_2} was measured by the method described by Schachter et al, with the following modifications.[10] After a patient was enrolled in the study, the nasopharynx was anesthetized with topical lidocaine 1%. To obtain samples of hypopharyngeal gas, a polyethylene catheter (PE-190) was prepared by making several side holes in the distal 1 cm of the catheter, to facilitate gas sampling, and then inserted into the nasopharynx, advanced approximately 5 cm distal to the naris, and secured with tape. The catheter was placed on the same side as the nasogastric tube, if one was in place, to prevent contralateral nasal airway obstruction by the catheter. Infants were allowed to stabilize for 30 minutes after insertion of the catheter, before the study samples were taken.

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Table 1. Physiologic Variables of Infants at the Time of the Study

	Mean ± SD	Range
Age (mo)	7.4 ± 4.2	2–17
Weight (kg)	6.0 ± 2.1	3.0–10.0
Weight percentile (%)	11.8 ± 18.3	1–70
Respiratory rate (breaths/min)	43.1 ± 12.2	22–71
Baseline S_{pO_2} (%)	97.5 ± 3.5	88–100
Lowest FIO_2 tolerated (%)	27.5 ± 8.8	21–48

S_{pO_2} = arterial oxygen saturation as measured via pulse oximetry
F_{IO_2} = fraction of inspired oxygen

A standard oxygen flowmeter (Precision Medical, Northampton, Pennsylvania, range 0–6 L/min) was connected to a 50 psi outlet supplied from the hospital bulk liquid oxygen system. A disposable infant nasal cannula (No. 1601, Salter Labs, Arvin, California) was used to administer oxygen. Hypopharyngeal gas samples were obtained at each of the following oxygen flows: 0, 0.5, 1.0, 2.0, 3.0, and 4.0 L/min, beginning at the lowest flow and progressing upward. Arterial oxygen saturation was measured continuously in all patients by pulse oximetry (oximeter model N-100, Nellcor, Pleasanton, California). If arterial oxygen saturation fell below 90% or by > 10% from baseline in infants with congenital heart disease, the oxygen flow was increased to the next highest level. Five minutes after the oxygen flow was changed, 30 mL of hypopharyngeal gas was withdrawn over 2 minutes into a plastic syringe and sealed with a stopcock. (We had previously determined that there was no loss of oxygen from or change in the F_{IO_2} in gas samples over 4 h using this type of syringe.) After obtaining gas samples at each flow, the sampling process was repeated. When duplicate measurements of the F_{IO_2} were available, the average of the 2 values was used to calculate the mean F_{IO_2} for each flow.

The partial pressure of oxygen and partial pressure of carbon dioxide in each gas sample were measured using standard electrodes (ABL-330, Radiometer, Copenhagen, Denmark). F_{IO_2} was calculated using the following equation:

$$F_{IO_2} = \frac{P_{O_2}}{(P_B - 47 \text{ mm Hg})}$$

wherein P_{O_2} is the partial pressure of oxygen, P_B is the barometric pressure (measured by the blood gas analyzer), and 47 mm Hg is the vapor pressure of water. Samples containing partial pressure of carbon dioxide < 10 mm Hg were assumed to have been contaminated by room air and were omitted from analysis. Also recorded were age, weight, diagnoses, respiratory rate, and whether the mouth was open or closed during gas sampling.

Mean F_{IO_2} values at each oxygen flow and between those with respiratory rate > or ≤ 40 breaths/min were compared using analysis of variance (ANOVA) for repeated measures and Student's *t* test. The percentages of patients receiving $F_{IO_2} > 60\%$ in one or more samples for each oxygen flow were compared by chi-square. Data are shown as mean ± SEM (except where indicated), with significance taken as $p < 0.05$.

Table 2. Major Diagnoses of Infants Studied

Diagnosis	*n*
Congenital heart disease	8
Pneumonia	7
AIDS	5
Chronic lung disease	4
Reactive airways	2
Hydrocephalus	1
Hepatitis	1
Dehydration	1

AIDS = acquired immunodeficiency syndrome.

Results

No serious complications resulted from placement of the hypopharyngeal catheter. Nasal secretions became blood-tinged after catheter insertion in several infants, but this resolved shortly after removing the catheter. Occasionally the catheter became plugged with secretions and had to be replaced.

Table 1 lists patient characteristics and physiologic measurements. Two patients were not infants (16 and 17 mo), but since their weights (10.0 and 8.7 kg) were within normal limits for a 12-month-old, they were included in the

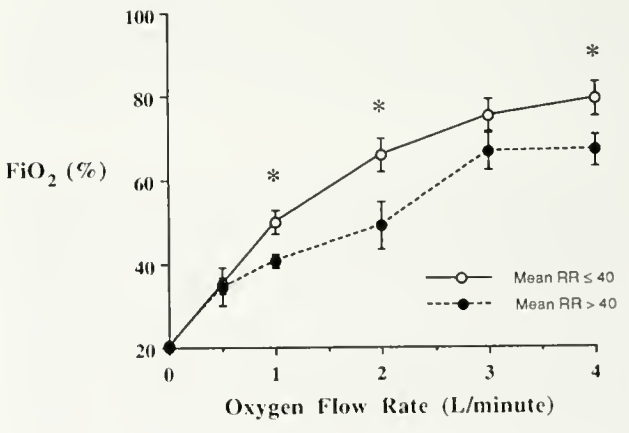

Fig. 1. Mean ± SEM values for fraction of inspired oxygen (F_{IO_2}) in infants with respiratory rates of > 40 breaths/min (solid circles) and ≤ 40 breaths/min (open circles). RR = respiratory rate in breaths/min. * $p < 0.05$ for comparisons between groups.

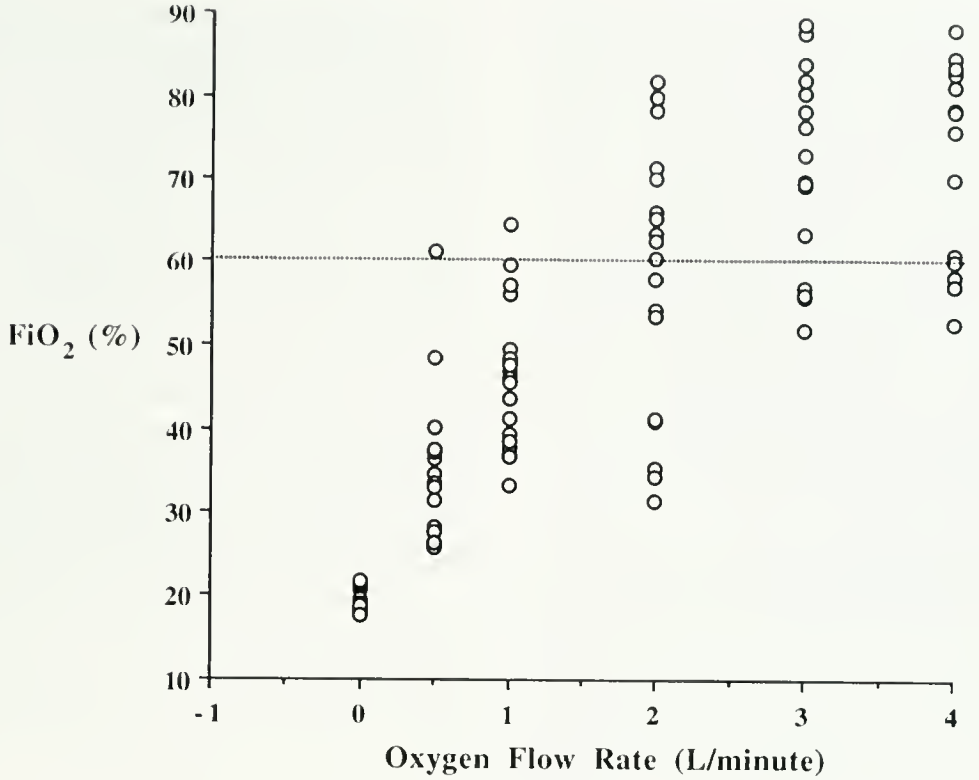

Fig. 2. Scatter plot of individual fraction of inspired oxygen (F_{IO_2}) measurements at various flows.

study. The mean percentile for weight was low (11.8 ± 4.0%), suggesting that many of these infants had chronic illnesses that impaired their growth. Table 2 lists the major diagnoses.

F_{IO_2} increased as the oxygen flow was increased. When infants received no supplemental oxygen, F_{IO_2} was 19.8 ± 0.4%. At oxygen flows of 0.5, 1.0, 2.0, 3.0, and 4.0 L/min, F_{IO_2} was 35.4 ± 1.7, 45.0 ± 1.8, 57.3 ± 3.7, 69.8 ± 2.5, and 72.7 ± 2.7%, respectively (Table 3). F_{IO_2} exceeded 60% in 63% of samples from the infants studied when the oxygen flow was 2.0 L/min or higher.

Respiratory rate > 40 breaths/min had a significant effect on F_{IO_2} at oxygen flows of ≥ 1.0 L/min. F_{IO_2} was lower in infants with respiratory rates of > 40 breaths/min (Figs. 1 and 2). In contrast, age, weight, or whether the mouth was open or closed did not affect F_{IO_2}.

Discussion

The nasal cannula has been used to deliver oxygen in unintubated patients for over 30 years[5] and has been firmly established as a safe route of oxygen administration for infants and children.[1–3] The present study shows that in non-neonatal infants (a group not previously studied) the hypopharyngeal F_{IO_2} delivered via nasal cannula at flows of ≥ 2 L/min commonly exceeds levels known to be associated with pulmonary oxygen toxicity. This finding underscores the need to measure F_{IO_2} in infants receiving oxygen at high flows (> 2 L/min) via nasal cannula for prolonged periods, in order to prevent oxygen toxicity.

The mean hypopharyngeal F_{IO_2} in adults receiving 100% oxygen via nasal cannula at 4 L/min has been found to be 32%, with a range of 26–39%.[6] The decrease in F_{IO_2} from the tip of the cannula to the hypopharynx is due to the large amount of air entrained from the environment during inspiration.[11,12] The F_{IO_2} in adults increases by approximately 2–6%/L/min of oxygen delivered via nasal cannula.[6,8,10,13] Even at flows of 10 L/min, F_{IO_2} does not exceed 60% in adults.[6] Our measurements of hypopharyngeal F_{IO_2}, which were obtained using the same methods as in the studies of adults, support the hypothesis that F_{IO_2} is higher in infants receiving oxygen via nasal cannula than in adults.

Several clinical factors have been shown to affect F_{IO_2} with various oxygen delivery systems.[8,9,13–16] In patients receiving oxygen via nasal cannula, F_{IO_2} varies inversely with peak inspiratory flow and directly with fresh gas flow.[14] Others have shown the same correlation with inspiratory and fresh gas flows with other delivery systems, such as air entrainment masks.[17]

Previous investigators have documented high F_{IO_2} when supplemental oxygen is supplied to neonates via nasal cannula. Fan and Voyles measured oropharyngeal F_{IO_2} in in-

fants < 3.5 kg at oxygen flows of ≤ 0.5 L/min, finding F_{IO_2} to be variable, ranging from 24% to 37%.[18] Finer et al found F_{IO_2} to be variable in infants < 1,500 g, ranging from 22% to 95% on various flows of 100% oxygen.[16] However, among the infants who weighed > 1,500 g, the highest achievable F_{IO_2} ranged from 29% to 47%, in an infant weighing 4,100 g. In larger infants on flows between 0.5 and 2 L/min, F_{IO_2} remained low, ranging from 28% to 35%.[18] Vain et al measured hypopharyngeal oxygen concentrations in 10 infants with a mean weight of 2.4 kg and also found unexpectedly high F_{IO_2} values.[19] These data were modeled mathematically to show that patient-independent factors such as oxygen flow and concentration, and patient-dependent factors such as inspiratory time, minute ventilation, and distribution of breathing, are important in determining F_{IO_2}.[20]

In our study, respiratory rate played a critical role in determining F_{IO_2}. Substantially more patients with respiratory rates < 40 breaths/min received potentially toxic F_{IO_2} levels than patients whose respiratory rate > 40 breaths/min. This is consistent with the previously reported finding that F_{IO_2} is inversely related to minute ventilation.[16] Although others have reported that nasal versus oral breathing can affect F_{IO_2}, we found no differences in F_{IO_2} when comparing samples taken while the mouth was open or closed.

There are several limitations to this study. First, the small number of patients did not allow us to determine precisely which infants were most likely to have high F_{IO_2} while receiving oxygen via nasal cannula. Higher F_{IO_2} in infants with respiratory rate ≤ 40 breaths/min suggests that infants with lower minute ventilation are at greatest risk of high oxygen exposure. Based on the aforementioned studies, it is likely that the smaller the infant, the greater the F_{IO_2} for any given oxygen flow.[13,16,19] Second, the nasopharyngeal gas samples were collected slowly, over 2 minutes, and contained a mixture of both inspiratory and expiratory gas. Therefore, the F_{IO_2} to which the distal airways were exposed during inspiration may have been much higher than what was measured in the nasopharyngeal samples. Substantial positive end-expiratory pressure can be delivered to an infant using a nasal cannula, which could be detrimental in the presence of obstructive lung disease.[21] However, because higher oxygen flows were administered for only 5 minutes prior to sampling, we do not think that inadvertent positive end-expiratory pressure affected the measurement of F_{IO_2} in this study.

Though the maximum safe F_{IO_2} is not firmly established, most clinicians agree that oxygen toxicity to the lungs occurs when a patient is exposed to F_{IO_2} > 60% for a prolonged period.[22–24] Recent guidelines by the Society of Critical Care Medicine recommend that the lowest possible F_{IO_2} be used at all times and that in patients with respiratory failure F_{IO_2} should not exceed 50%.[25] This reflects the concern that exposure to even low concentrations of oxygen can contribute to lung injury because many of the endogenous free radical defense mechanisms are impaired in the setting of acute lung injury.[22,23] The present study shows that infants receiving oxygen via nasal cannula at ≥ 2 L/min may be at risk for hyperoxic lung injury.

Table 3. Oxygen Flow Rates and Resultant F_{IO_2}

n	Flow (L/min)	F_{IO_2} (%)	Patients (%) with F_{IO_2} > 60%*	Samples (%) with F_{IO_2} > 60%
11	0	19.8 ± 0.4	0/11 (0)	0/19 (0)
17	0.5	35.4 ± 1.7	1/17 (6)	2/31 (6)
20	1.0	45.0 ± 1.8	3/20 (15)	3/38 (8)
20	2.0	57.3 ± 3.7	11/20 (55)	18/35 (51)
17	3.0	69.8 ± 2.5	12/17 (71)	17/26 (65)
15	4.0	72.7 ± 2.7	13/15 (87)	20/26 (77)

F_{IO_2} = fraction of inspired oxygen
Values are mean ± SEM
*The number of patients (*n*) who had measurements at each flow rate varied because of insufficient sample or inability to tolerate low oxygen flow rates

Conclusion

In conclusion, we found that in non-neonatal infants, toxic levels of oxygen can be delivered via nasal cannula. We therefore recommend using the lowest possible oxygen flow or blending air with oxygen in order not to administer toxic levels of oxygen to infants receiving prolonged oxygen therapy.

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Utility of Measurements of Oxygen Cost of Breathing in Predicting Success or Failure in Trials of Reduced Mechanical Ventilatory Support

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OBJECTIVE: Test whether a change in oxygen consumption produced by a reduction in level of mechanical ventilatory support predicts failure to tolerate the reduction in level of support. DESIGN: Prospective study of the sensitivity and specificity of increased oxygen cost of breathing as a predictor of failure to tolerate a reduction in ventilatory support in patients undergoing weaning, using a protocol that incrementally reduces the level of mechanical ventilatory support. SETTING: University medical center. METHODS: We studied 228 trials in 30 patients who had required mechanical ventilatory support for at least 72 hours and who were being weaned using a standardized protocol that provided for three 30-minute trials of reduced mechanical ventilatory support per day, followed by ventilatory muscle rest. Using a metabolic monitor, we monitored oxygen consumption ($\dot{V}_{O_2}$) prior to and during 228 incremental reductions in level of mechanical ventilatory support conducted as part of a standardized weaning protocol. Oxygen cost of breathing was defined as the difference in $\dot{V}_{O_2}$ ($\Delta\dot{V}_{O_2}$) during the trial of reduced mechanical ventilatory support, compared to a 30-minute resting period immediately before the trial. A successful trial was defined as one that could be continued for 30 minutes without development of clinical signs of ventilatory failure. Changes in $\dot{V}_{O_2}$ and the ratio of respiratory frequency to tidal volume (f/V_T) during a weaning trial were evaluated as predictors for failure of a 30-minute trial of reduced ventilatory support. RESULTS: A 15% increase in oxygen cost of breathing predicted failure in the trial, with a sensitivity of 96.6%, specificity of 85.7%, positive predictive value of 98.5%, and negative predictive value of 72.0%. Neither change in $\dot{V}_{O_2}$ measured early in the trial nor f/V_T proved to be as successful in predicting failure to tolerate an incremental reduction in ventilatory support. CONCLUSION: Change in $\dot{V}_{O_2}$ following an incremental reduction in level of mechanical ventilatory support may be a useful predictor for determining which patients will rapidly fail to tolerate that level of reduction. *Key words: oxygen cost of breathing, oxygen consumption, weaning, mechanical ventilation, ventilatory failure, structured ventilatory protocol, clinical measures.* [Respir Care 2001;46(9):902–910]

Introduction

Weaning is described as a process of gradually reducing mechanical ventilatory support as a patient's own respiratory system recovers from disease.[1] The majority of patients requiring mechanical ventilation can be weaned without difficulty once the disease process necessitating ventilatory support resolves. However, a fraction of patients do not tolerate rapid withdrawal of ventilatory support, and these patients utilize a disproportionate share of intensive care resources.

There are conflicting data in the literature[2,3] as to whether patients are more rapidly weaned using trials of spontaneous breathing or by incremental reductions in either pres-

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sure support ventilation or level of synchronized intermittent mandatory ventilation (SIMV). A large evaluation of weaning techniques used in the United States and Canada indicated that 5% of physicians preferred to use reductions in SIMV as a primary method of weaning, 41% preferred pressure support ventilation, 32% preferred SIMV with pressure support ventilation, 9% preferred intermittent spontaneous breathing trials, and 7% preferred daily spontaneous breathing trials.[4] Almost all of these approaches involve either incremental reductions in the level of ventilatory support or transient complete withdrawal of ventilatory support.

While there is still a lack of consensus on the most effective weaning modalities, protocol-based weaning has been demonstrated to be superior to individualized approaches.[5-9] At least 2 randomized controlled trials have demonstrated the superiority of a nurse-directed or respiratory therapist-directed protocol, compared to the usual care of physician-directed weaning.[6,8] These protocols involve repetitive incremental reductions in the level of ventilatory support, transient complete withdrawal of ventilatory support, or a sequential application of both approaches. Termination of the weaning trials in these protocols were based on clinical and physiologic evidence of ventilatory failure, including increasing respiratory and cardiac rates and falling oxygen saturation. The time required to progress through these standardized weaning protocols is likely to be reduced if better measures are available to evaluate whether patients will be able to tolerate specific levels of reduction in ventilatory support, allowing more rapid progression to full spontaneous breathing.

Measures do exist to predict which patients will tolerate complete withdrawal of mechanical ventilatory support and extubation.[10-12] Yang and Tobin[10] described a ratio of respiratory frequency to tidal volume (f/V_T) of 105 as a valid predictor, but the value for the f/V_T ratio felt to be the most reliable cutoff remains controversial.[13] An oxygen cost of breathing, calculated as the difference between the oxygen consumption ($\dot{V}_{O_2}$) calculated during spontaneous breathing and that calculated on total mechanical ventilatory support of $< 15\%$ of the resting $\dot{V}_{O_2}$ also predicts successful withdrawal of ventilatory support.[14-18] We postulate that these measures, which are useful in predicting successful extubation, might also be useful in predicting whether patients would tolerate incremental reductions in level of ventilatory support.

Clinical measures, including changes in spontaneous V_T and respiratory rate, as well as development of hypoxia or agitation, are commonly used to assess whether a patient is tolerating a reduction in level of ventilatory support, but scant data exist to predict the magnitude of reduction in support a patient will tolerate or how rapidly subsequent reductions in support can progress. Measures that assess the extent to which and rapidity with which ventilatory support can be successfully reduced are likely to improve the design, evaluation, and cost-effectiveness of structured approaches to weaning patients who present difficult weaning problems.

At the University of California San Diego Medical Center (UCSDMC), patients who fail to wean from mechanical ventilation with an initial attempt at progressive reduction in ventilatory support are placed in a structured ventilatory weaning protocol that uses incremental reductions in the level of mechanical ventilatory support, interspersed with periods of respiratory muscle rest produced by full mechanical ventilatory support. The protocol defines specific criteria for success or failure based on overt clinical signs and physiologic measures of ventilatory failure. The use of this protocol provides an opportunity to examine a group of patients who have failed initial weaning attempts. Measurements of $\dot{V}_{O_2}$ can be made as they are placed on partial ventilatory support for short trials. By using the care delivery team's decisions on the success or failure of these trials, we can prospectively evaluate the utility of the change in oxygen consumption ($\Delta\dot{V}_{O_2}$) and the f/V_T ratio for predicting failure to tolerate each incremental reduction in support.

Methods

Study Design

This was a prospective study of predictors of success or failure in 30-minute trials of incremental reduction in level of ventilatory support among patients who had required mechanical ventilatory support for at least 72 hours, who had failed at least one weaning attempt using progressive reduction of ventilatory support, and who were currently being weaned from mechanical ventilation using a standardized protocol. $\dot{V}_{O_2}$ was measured prior to and during trials of reduced mechanical ventilatory support. $\Delta\dot{V}_{O_2}$ and f/V_T measured at the end of a trial were evaluated for their ability to predict success or failure in the trial. Success or failure in tolerating a reduction in level of mechanical ventilatory support without developing clinical signs of respiratory failure was used as the outcome measure for evaluating the sensitivity and specificity of these measures.

Subject Selection

Our study examined subjects admitted to the medical, surgical, and burn intensive care units at UCSDMC who required mechanical ventilatory support for at least 72 hours and who had failed to successfully wean from mechanical ventilation on a continuous positive airway pressure trial or with rapid sequential reductions in the inter-

Table 1. Characteristics of the 30 Patient Participants

	MICU	SICU	BICU	Total
Patients (*n*) (M:F)	14 (3:11)	13 (8:5)	3 (3:0)	30 (16:14)
Trials (*n*)	102	110	16	228
Mean age (y) (range)	59.0 (27–86)	44.9 (18–79)	42.0 (30–53)	51.2 (18–86)
Mean LOS (d) (range)	43.2 (21–84)	50.5 (18–78)	44.3 (30–70)	46.6 (18–84)
Mean $\dot{V}O_2$ at rest (mL/min) (SD)	283.1 (51.3)	333.8 (56.2)	522.0 (53.4)	328.6

MICU = medical intensive care unit
SICU = surgical intensive care unit
BICU = burn intensive care unit
LOS = length of stay in hospital

mittent mechanical ventilation (IMV) rate. Most of the patients required mechanical ventilation because of acute lung injury rather than chronic respiratory failure. The average length of mechanical ventilation was over 40 days, indicating that this was a severely compromised group of patients. Only trials of reduced support delivered as part of a structured weaning protocol were considered. Table 1 lists patient diagnoses and other characteristics.

At the time of the trial of reduced support, patients were required to be age 18 years or older and in stable hemodynamic condition. The study protocol excluded pregnant women and patients with thoracostomy tubes. Patients who were capable of understanding gave informed consent. For patients unable to give consent, consent was obtained from a legal representative.

Data Collection and Analysis

A ventilator (NPB 7200ae, Nellcor Puritan Bennett, Pleasanton, California) and a metabolic monitor (7250, Nellcor Puritan Bennett, Pleasanton, California) were used with all patients. The metabolic monitor measured $\dot{V}_{O_2}$, carbon dioxide production ($\dot{V}_{CO_2}$), energy expenditure, and respiratory quotient noninvasively and continuously, generating an updated measurement every 20 seconds. The NPB 7250 monitor is mounted on top of the NPB 7200ae ventilator and is integrated with the ventilator both pneumatically and electronically. Communication with the ventilator occurs through a digital interface. The technical specifications, operation procedures, and validation of this system have been previously described,[19] and the precision of measurement of the device for $\dot{V}_{O_2}$ is within 7%.

Resting pre-trial oxygen consumption was measured continuously and values were updated every 20 seconds for a 30-minute period of stable mechanical ventilation with no spontaneous ventilatory activity pre-trial. Oxygen consumption during the trials of reduced support was also measured continuously. Within each trial, the mean values for the continuous measurements were calculated for specific time intervals.

The definition of oxygen cost of breathing or $\Delta\dot{V}_{O_2}$ used in this study is the difference in mean value of the oxygen consumption measurements made during the 30-minute trial of reduced ventilatory support minus the mean value of the continuous oxygen consumption measurements made during a 30-minute baseline pre-trial period of full ventilatory support without spontaneous ventilatory activity. The $\dot{V}_{O_2}$ measurements were collected as shown in Figure 1 and are expressed as a percentage of the baseline $\dot{V}_{O_2}$ value. The baseline $\dot{V}_{O_2}$ is calculated as the mean of the measurements made for 30 minutes of stable ventilation with no spontaneous ventilatory activity pre-trial (A in Fig. 1). Following the baseline collection, the patient's continuous mandatory ventilation (CMV) rate was reduced until a stable rate of spontaneously initiated CMV breaths was observed. The mode of mechanical ventilation was then switched to SIMV at a reduced rate specified by the weaning protocol, and a trial of reduced ventilatory support was initiated. Measurements made during the first 5 minutes after changing the mode of mechanical ventilation to IMV were discarded in order to reduce the distortion of the $\dot{V}_{O_2}$ measurements produced by the patient's adjustment to the change in level of ventilatory support. Data collection for $\dot{V}_{O_2}$ during the trial began after this 5-minute adjustment period (B in Fig. 1).

We also examined the value of $\Delta\dot{V}_{O_2}$ measurements made for shorter periods at the beginnings and ends of the weaning trials. The $\dot{V}_{O_2}$ for the first 5 minutes of data collection in the trial (5–10 minutes after the patient is switched to IMV) minus the baseline $\dot{V}_{O_2}$ (C in Fig. 1) was recorded in order to evaluate the utility of measurements made shortly after the initiation of a weaning trial for predicting the success or failure of the trial.

In order to evaluate changes in $\dot{V}_{O_2}$ with onset of ventilatory failure, we calculated the $\dot{V}_{O_2}$ for the last 5 minutes of the trial (D in Fig. 1) compared to the baseline $\dot{V}_{O_2}$. This measure was intended to separate the increment in $\dot{V}_{O_2}$ produced by the onset of ventilatory failure at the end of the trial from that resulting from the reduction in the level of mechanical ventilatory support.

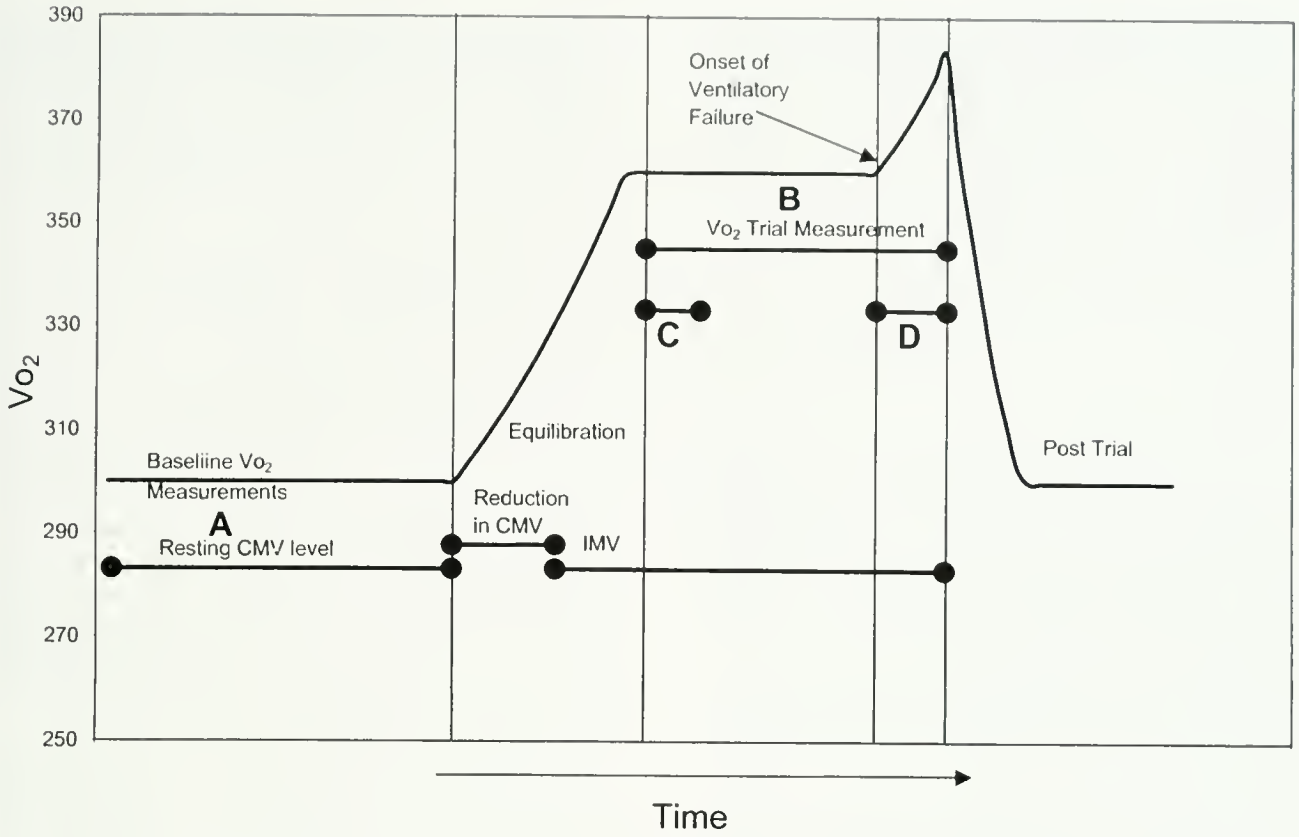

Fig. 1. Timing of measurements of oxygen consumption ($\dot{V}_{O_2}$) prior to and during a trial of reduced mechanical ventilatory support. A: Baseline $\dot{V}_{O_2}$ measurements. B: Onset of data collection following 5-minute adjustment period. C: Measurement interval of $\Delta\dot{V}_{O_2}$ first 5 minutes versus pre-trial: difference between baseline $\dot{V}_{O_2}$ and $\dot{V}_{O_2}$ measured during the period 5–10 minutes from the start of the trial. D: Measurement interval of $\Delta\dot{V}_{O_2}$ last 5 minutes versus pre-trial: difference between baseline $\dot{V}_{O_2}$ and $\dot{V}_{O_2}$ during the last 5 minutes of the trial. CMV = continuous mandatory ventilation. IMV = intermittent mandatory ventilation.

Also evaluated was f/V_T, calculated as the average of measurement of V_T and respiratory rate during the last 5 minutes of the trial.

Weaning Protocol

The standardized clinical ventilatory weaning protocol used at UCSDMC is intended to provide three 30-minute trials per day of spontaneous ventilatory effort at a level likely to induce ventilatory muscle fatigue and produce clinical evidence of ventilatory failure. Between these periods, the patients are ventilated at a CMV rate high enough to suppress spontaneous ventilatory efforts and rest the ventilatory muscles. In order to identify the maximum reduction in IMV rate that the patient will tolerate, the protocol begins with a 2-hour period of respiratory muscle rest, during which the patient is ventilated in the assist/control mode at a rate sufficient to suppress the spontaneous respiratory rate. Following this period of rest, the respiratory rate of the mechanical ventilator in the CMV mode is decreased until the patient reestablishes a stable rate of spontaneously triggering mechanical ventilator-delivered breaths. The patient is allowed to reestablish a stable spontaneous ventilatory rate in the CMV mode for at least 10 minutes prior to initiation of each trial. Once the respiratory rate in the CMV mode is stable, the ventilator mode is switched to SIMV and the set mechanical ventilator rate is reduced to 80% of the rate at which the mechanical ventilator assisted each breath. If the patient successfully tolerates that level of reduction in SIMV rate for 30 minutes without clinical signs of ventilatory failure, the rate is decreased by 2 breaths/min with each subsequent trial until the patient shows clinical signs of ventilatory failure within the 30-minute trial. That level of SIMV is selected for subsequent trials until the patient is able to tolerate the level of reduction for 30 minutes without clinical signs of ventilatory failure, at which time the SIMV set rate is again lowered by 2 breaths/min. This process continues until the patient is able to tolerate 30 minutes at a set rate of zero.

The clinical signs used to define ventilatory failure are an increase in respiratory rate to > 30 breaths/min or an

increase in heart rate of > 10 beats/min, or development of hypoxemia, hypotension, or agitation. Once evidence of ventilatory failure is judged to be present, the trial is terminated and the patient placed back on full ventilatory support. Three trials are performed per day, with the patient rested on the ventilator between trials, using an IMV or CMV respiratory rate setting high enough to eliminate spontaneous ventilatory efforts.

Once the patient is able to tolerate 30 minutes on an SIMV of zero, the duration of the trials is extended, using the same criteria for termination of the trial, until the patient is able to ventilate for 24 hours without mechanical ventilatory support.

All decisions to enter patients into the protocol, progress in reduction of IMV rate, or terminate a trial as a failure were made by the care delivery staff, without access to the measurements made for purposes of this study. The investigators measured $\dot{V}_{O_2}$ and recorded ventilatory parameters, but did not participate in care delivery or weaning decisions, and they did not make the decision as to whether the trial was judged a success or a failure.

Definition of Ventilatory Failure and Determination of Success or Failure of a Trial

If, in the judgment of the care delivery team, the criteria for trial failure under the protocol were met, the trial was terminated prior to the end of the 30-minute period. When a trial could be continued 30 minutes without development of clinical ventilatory failure by protocol criteria, the trial was regarded as a success. When the trial was terminated at < 30 minutes under the protocol criteria, the trial was regarded as a failure. All decisions to terminate a trial were made independently by the care delivery team, without input from the study investigators.

Statistical Analysis

The analytic question being asked herein is the sensitivity and specificity of measures predicting failure to tolerate a trial of incremental reduction in the level of mechanical ventilatory support, and not whether individual patients will successfully wean from mechanical ventilation. The structured weaning protocol provides for the possibility of trial failure without regard to the success or failure of the previous trial. However, successful weaning is often heavily influenced by individual patient characteristics, and this influence may make the trials for any given patient more likely to have a similar result. This concern raises the question of whether the 228 trials can be analyzed as independent trials or whether, instead, the data should be analyzed as a repeated measures experiment on 30 subjects.

In order to respond to this issue, the independence of the success/failure of the separate trials for a given subject was tested. If the success/failure of the various trials is independent of subject, then the number of failures for a given number of trials follows a binomial distribution. The number of trials for an individual is assumed to be a random variable with a common probability of failure for each trial, as calculated from the data p = 21 failed trails/228 total trials = 0.0921. The observed distribution of numbers of failed trials for each subject was then tested against the expected number of failures given the number of trials for that individual, with expected values and variance estimated from the binomial distribution. The sum of the normalized squared-deviations results in a chi-square of 25.05 on 29 degrees of freedom, p = 0.675. Thus, there is no evidence that the number of failures does not follow an independent binomial distribution. The likelihood of failure on a given trial is independent of the number of trials for the subject, with no statistical tendency for greater or lesser numbers of failures for particular subjects than that expected from an independent binomial distribution, nor is there any relationship of success/failure associated with the number of trials for an individual subject.

Further, there is no evidence of time trends in $\Delta\dot{V}_{O_2}$ with successive trials, either across subjects or within subjects. Testing for a time trend within subjects, we find no general trend for increasing or decreasing $\Delta\dot{V}_{O_2}$ values with successive trials. Within-subject slopes regressed on trial sequence range from –3.82 to 12.50, mean = 0.2157 (SD = 3.0776), for subjects with 3 or more trials, the mean not significantly differing from 0.0. Across subjects, the coefficient of trend has a slope of 0.01228 (SE = 0.13792), also not significantly different from 0.0.

The evidence indicating that failure is independent of number of trials for a subject and the lack of a time trend with successive trials supports treating the observations as independent in bootstrapping and regression modeling. Confidence intervals were then generated from bootstrap resampling. The 288 data points were treated as independent data points and subjected to 1,000 repeated resampling trials with replacement, using the bootstrap function in the S-PLUS 2000 program (Insightful Corporation, Seattle, Washington). Both the sensitivity and specificity were tabulated for each of the 1,000 resamples for a range of test cut-points from 10 through 20. The observed range of values from the collection of resamples provides empirical estimates of 95% confidence intervals. The bias-corrected values are those that are reported.

We also used an alternative method of deriving a level of confidence for the results, which was to model the data and assess the goodness of fit of the model. The empirical sensitivity and 1-specificity values were calculated for each observed $\%\Delta\dot{V}_{O_2}$ value, providing 288 data points with an associated data pair. These points were fit with a logistic

regression to generate the $\Delta\dot{V}_{O_2}$ levels that correspond to specified levels of sensitivity, and the confidence intervals for the specificity at those levels of $\Delta\dot{V}_{O_2}$ were estimated.

Standard formulas were used to calculate the sensitivity, specificity, positive predictive value, and negative predictive value of each index,[20] as follows:

$$\text{Sensitivity} = \frac{\text{True positives}}{\text{True positives} + \text{False negatives}} \quad (1)$$

$$\text{Specificity} = \frac{\text{True negatives}}{\text{True negatives} + \text{False positives}} \quad (2)$$

$$\text{Positive predictive value} = \frac{\text{True positives}}{\text{True positives} + \text{False positives}} \quad (3)$$

$$\text{Negative predictive value} = \frac{\text{True negatives}}{\text{True negatives} + \text{False negatives}} \quad (4)$$

Results

We recorded 228 trials from 30 patients in this study (see Table 1). There were 16 men and 14 women, 14 medical patients, 13 surgical patients, and 3 burn injury patients. The mean age was 51.2, with a range of 18 to 86. Mean length of stay in the hospital was 46.6 days (range 18 to 84 d). Though all patients were on mechanical ventilation for at least 72 hours, the etiology of the requirement for continued ventilatory support was predominantly acute (not chronic) respiratory failure. Twenty-five of the 30 patients were ultimately weaned from ventilatory support, with two requiring long-term tracheotomy at time of discharge. Four patients had died and one was still on mechanical ventilation at the end of the study. The mean for the baseline $\dot{V}_{O_2}$ measurements at the start of each trial of reduced support was substantially higher for burn injury patients than for medical and surgical patients.

Table 2. Change in Oxygen Consumption as a Predictor of Success or Failure in Tolerating a 30-Minute Trial of Reduced Ventilatory Support

$\Delta\dot{V}O_2$	Success	Failure	Sensitivity	Specificity	PPV	NPV
< 15%	200	3	96.5%	85.7%	98.5%	72.0%
≥ 15%	7	18				

$\Delta\dot{V}O_2$ = difference between pre-trial baseline oxygen consumption and oxygen consumption during the 30-minute weaning trial
PPV = positive predictive value
NPV = negative predictive value

Table 3. Change in Oxygen Consumption During a Reduction in Mechanical Ventilatory Support Required to Achieve Specified Levels of Sensitivity in Predicting Failure to Tolerate the Reduced Support

Sensitivity	Specificity (95% CI)	$\Delta\dot{V}O_2$ Cut Point
0.8	0.885 (0.864–0.906)	7.80%
0.9	0.852 (0.823–0.884)	10.70%
0.95	0.822 (0.785–0.859)	13.60%
0.975	0.792 (0.748–0.837)	15.50%

$\Delta\dot{V}O_2$ = change in oxygen consumption.

There were 207 successful trials and 21 failed trials of reduced ventilatory support. The average $\Delta\dot{V}_{O_2}$ during the trial was 1.7% in successful trials and 20.4% in failed trials. Two hundred of the 207 successful trials had $\Delta\dot{V}_{O_2} < 15\%$, and 18 of 21 failed trials had $\Delta\dot{V}_{O_2} > 15\%$. For a level of $\Delta\dot{V}_{O_2} = 15\%$, the sensitivity was 96.5 (93.7–98.1, 95% confidence interval), the specificity was 85.7 (66.7–95.6, 95% confidence interval), the positive predictive value was 98.5%, and the negative predictive value was 72.0% (Table 2).

The $\Delta\dot{V}_{O_2}$ corresponding to different levels of sensitivity and specificity was estimated by modeling the data, and confidence intervals were defined from the goodness of fit of the model. Table 3 presents those values.

Table 4 shows the percentage of failed trials at various levels of $\Delta\dot{V}_{O_2}$, with the $\Delta\dot{V}_{O_2}$ calculated using the average for the entire trial excluding the first 5 minutes, the average for the period 5–10 minutes into the trial, and the average for the last 5 minutes of the trial. The percentage of failed trials is also recorded for different levels of f/V_T measured at the end of the trial. A clear threshold for defining failure was evident for the average of the entire trial, compared to the 30-minute baseline period, with the failure rate increasing dramatically with $\Delta\dot{V}_{O_2} > 15\%$. When failure rates were calculated for $\Delta\dot{V}_{O_2}$ measurements made for shorter time intervals, either early in the trial or at the end of the trial, failure rates increased with increasing $\Delta\dot{V}_{O_2}$, but there was no clear threshold for defining failure. Values of f/V_T measured at the end of the trial were not systematically related to the success or failure of a trial.

Discussion

Most mechanically ventilated intensive care unit patients can be extubated in < 72 hours.[1] However, because of the long duration of their mechanical ventilatory support, patients who are difficult to wean represent a sub-

Table 4. Percentage of Trials Ending in Failure with Various Measures of Oxygen Cost of Breathing and with the Ratio of Respiratory Frequency to Tidal Volume

$\Delta\dot{V}O_2$ (%)	$\Delta\dot{V}O_2$ with Reduction in Ventilatory Support			f/V_T	
	Pre-trial* vs Trial (%)	Pre-trial* vs Minutes 5–10 of Trial (%)	Pre-trial* vs Last 5 min of Trial (%)	Value	% Failure
< 5	1.4	4.4	1.8	< 75	1.8
5–9	2.4	2.4	0.0	75–90	16.7
10–14	0.0	12.0	6.3	90–104	4.3
15–19	55.6	27.3	12.5	105–119	18.2
20+	81.3	100.0	58.3	120+	19.4

$\Delta\dot{V}O_2$ = oxygen cost of breathing (change in oxygen consumption)
f/V_T = ratio of respiratory frequency to tidal volume.
*Pre-trial = 30 minute measurement period before the weaning trial.

stantial fraction of the ventilator days in most intensive care units. Structured approaches to weaning these patients using protocol-based approaches have demonstrated substantial reductions in the duration of mechanical ventilation required before successful weaning,[5–9] compared to usual care physician-initiated approaches.

These protocols involve incremental reductions in SIMV rate,[5] repetitive trials of spontaneous breathing,[6,7] or a combination of the two.[8,9,21] Premature termination of the trials in these weaning protocols was based on clinical evidence of ventilatory failure, and currently no validated measures exist for predicting failure to tolerate a reduction in ventilatory support other than the development of actual ventilatory failure. Measures do exist that can predict the success or failure of complete withdrawal of ventilatory support, and this study explored the utility of some of those measures in predicting patient tolerance of incremental reductions in ventilatory support as part of a weaning protocol.

Several studies[16–18,22,23] have examined the value of $\Delta\dot{V}_{O_2}$ (defined as the difference in $\dot{V}_{O_2}$ between total mechanical ventilation and unsupported spontaneous ventilation) as a predictor of successful extubation. In those studies, the criterion for success or failure was whether the patient could be successfully extubated. In a retrospective evaluation, Lewis et al[16] reported that a $\Delta\dot{V}_{O_2} < 15\%$ correlated well with the patient's ability to tolerate removal of ventilatory support. In a prospective evaluation, Shikora et al[17,18] found that when $\Delta\dot{V}_{O_2}$ was elevated > 15%, patients were unlikely to succeed with extubation. Shikora et al evaluated patients receiving long-term mechanical ventilation, using a $\Delta\dot{V}_{O_2}$ value of 15%, and found a sensitivity of 100% and a specificity of 80% for successful extubation.

$f/V_T > 105$ has also been established by Yang and Tobin[10] as a valid predictor for successful extubation, but the value for the f/V_T ratio felt to be the most reliable cutoff remains controversial.[13]

Success in using these measures to predict successful extubation led us to evaluate whether $\Delta\dot{V}_{O_2}$ could be usedto predict patient tolerance of a given reduction in level of ventilatory support as part of a weaning protocol. With the availability of convenient and noninvasive $\Delta\dot{V}_{O_2}$ measurement, changes in $\dot{V}_{O_2}$ arising from changes in level of ventilatory support can become part of the data used to evaluate patients suffering ventilatory failure. We present data on changes in $\dot{V}_{O_2}$ that occurred when the level of ventilatory support was reduced in a group of patients who were not ready for extubation. The results indicate that patients with greater increases in $\dot{V}_{O_2}$ following reduction in level of ventilatory support have a greater likelihood of developing clinical evidence of ventilatory failure within 30 minutes of the reduction of support. In addition, the likelihood of failure increases dramatically when the increase in $\dot{V}_{O_2}$ exceeds 15%.

The measure of success used in our study was the patient's completion of a trial of increased ventilatory work imposed by a reduction in the ventilator IMV rate without developing signs of ventilatory failure as assessed by the care delivery team. Some of the patients who did not show signs of ventilatory failure at 30 minutes might have developed signs of ventilatory failure if they had been allowed to continue their trials for longer periods, but this study was designed to examine a limited-duration trial rather than reductions of ventilatory support that could be tolerated indefinitely, and the data should not be presumed to predict the results of longer trials.

We also examined whether measurements of $\dot{V}_{O_2}$ for shorter periods could be substituted for the average for the entire 30-minute trial. Measurements taken early in the trial (the average of the values from 5–10 minutes into the trial) and measurements taken over the last 5 minutes

of the trial were evaluated. Neither provided as clear a threshold for defining success or failure.

The absence of a threshold for $\Delta\dot{V}_{O_2}$ measurements made during short periods, either early or late in the trial, may relate to the different patterns of adjustment to reductions in level of ventilatory support. In some trials, the early $\Delta\dot{V}_{O_2}$ average was high and settled back down to lower values as the trial progressed. In other instances, the early $\Delta\dot{V}_{O_2}$ underestimated the average for the entire trial, probably because the patient had not fully equilibrated to the change in mechanical ventilation by 5 minutes into the trial.

Similar discrepancies were noted for the measurements taken over the last 5 minutes of the trial and may relate to the likelihood that many of the patients were becoming fatigued by the end of the trial, thus increasing their $\dot{V}_{O_2}$. This increase in $\dot{V}_{O_2}$ at the end of the trial did not produce evidence of clinical respiratory failure sufficient to lead the care delivery team to terminate the trial within the 30-minute trial period and therefore may have generated a false positive prediction of failure. It remains to be determined whether continuous monitoring of $\dot{V}_{O_2}$ during the trial to identify a sudden change in $\dot{V}_{O_2}$ as the trial progresses would be a useful approach to defining the onset of ventilatory failure or respiratory muscle fatigue.

We also examined the possibility of using the average of $\dot{V}_{O_2}$ for only 5 minutes as a baseline measure of $\dot{V}_{O_2}$ instead of a 30-minute average. Using the average of the 5 minutes prior to the start of the trial resulted in substantial variability in the baseline measurement, compared to the 30-minute value, and significantly reduced the predictive value of those measurements. There is probably substantial variability in the $\dot{V}_{O_2}$ over time, and 5 minutes may not be long enough to obtain a representative and stable baseline measurement of resting $\dot{V}_{O_2}$.

Conclusions

The observations presented in this study may be useful in guiding protocol-based weaning, by providing a useful predictor of the level of reduction in mechanical ventilatory support that a patient is likely to tolerate for sustained periods, as well as those reductions likely to produce ventilatory failure. This may facilitate more rapid progression through the weaning protocol. It remains to be determined in additional trials whether incorporation of $\Delta\dot{V}_{O_2}$ measurements as part of the decision tree in a weaning trial actually improves the rapidity or success of efforts to wean patients from mechanical ventilatory support.

In summary, the difference between $\dot{V}_{O_2}$ measured during a weaning trial and that during a resting period may be a useful predictor of the patient's ability to tolerate a given reduction of mechanical ventilatory support without developing clinical ventilatory failure. A $\Delta\dot{V}_{O_2}$ of $\geq$ 15% predicts that a patient will develop clinical signs of ventilatory failure during a 30-minute trial of reduced mechanical ventilatory support.

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What's New in Thoracic Imaging?

Eric J Stern MD

With the advent of the technologic age, there have been remarkable advances in the imaging sciences. As such, the beginning of our new millennium brings remarkable new imaging tools to bear on patient diagnosis and treatment. Even the venerable "plain x-ray" is no longer that, but now a remarkably sophisticated "computed radiograph" that can be archived on a hospital computer system. In a modern radiology department, computed radiography is part of a fully integrated picture archive system.

However, the greatest technologic and diagnostic advances in imaging of the heart and lungs, in health and disease, has taken place across the entire array of cross-sectional imaging tools: multi-detector computed tomography (CT) scanners, magnetic resonance imaging (MRI), ultrasound, and nuclear imaging. Recent articles in the lay press have touted the technologic advances in both hardware and software of multi-detector CT scanning to be called the "virtual checkup," with a potential role in the early detection of disease. Similar advances in MRI are providing not just anatomic depictions of diseases but are allowing physiologic characterization of disease states, giving us new windows into the anatomy, cell structure, and histopathology of living tissues. These imaging modalities are noninvasive or minimally invasive and can be used to take serial "virtual biopsies" or snapshots of target organs and tissues in living animals over time.

Exciting physiologic advances are also being seen in nuclear imaging, especially with regard to cancer evaluations and imaging at the cellular and molecular levels, with molecular probes and contrast agents. Molecular probes are often signal-producing agents linked to drugs or proteins, designed to be specific for a particular molecule or biological process.

We are also now witnessing a far-reaching change in image-guided therapy. We are at the threshold of real-time imaging of anatomy, physiology (eg, blood flow, neuron activation) and function during surgery, video imaging in laparoscopic surgery, image-guided placement of catheters and other devices, and surgical computer-aided design and distance medicine. There are new interventional imaging techniques such as thermal coagulation via focused ultrasound. Molecular and other imaging modalities can be used to monitor drug delivery and action, gene expression, or metabolism. Developments in hardware and software in CT, MRI, ultrasound, positron emission tomography, and single photon emission CT, in concert with clinician-directed applications, have made this possible.

Partly in recognition of these advances, the United States Congress has created, by statute, the National Institute of Biomedical Imaging and Bioengineering (NIBIB). The NIBIB, the newest of the National Institutes of Health (NIH), was signed into law in December of 2000. The mission of the NIBIB is to support the fundamental research that applies the principles of engineering and imaging science to biological processes, disorders, and diseases. The institute will facilitate the transfer of this basic research to medical application. Dr Ruth Kirschstein, acting director of the NIH, stated that, "while dedicating an institute to medical technologies rather than to diseases, organ systems, or populations may seem novel for the NIH, it is truly a reflection of what science is today—and where science will be taking us tomorrow."[1]

This special issue of RESPIRATORY CARE focuses on what's new in thoracic imaging. The authors are nationally recognized authorities in imaging and are on faculty at major university hospital tertiary care referral centers. The articles presented are meant to provide an overview of our exciting new imaging world.

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Multidetector-Row Spiral Computed Tomography in the Diagnosis of Thoracic Diseases

Samuel K Dawn MD, Michael B Gotway MD, and W Richard Webb MD

Introduction
Multidetector-Row Spiral Computed Tomography
  Advantages of Multidetector-Row Computed Tomography
  Multiplanar Reconstruction
  Three-Dimensional Reconstruction
Clinical Applications of Multidetector Spiral Computed Tomography
  Computed Tomography Pulmonary Angiography
  Computed Tomography Aortography
  Detection of Lung Modules and Diagnosis of Lung Disease
  Airway Imaging
Summary

Since its introduction in 1992, spiral computed tomography (CT) scanners constructed with a single row of detectors have revolutionized imaging of thoracic diseases. Current state-of-the-art models use up to 16 detectors and are capable of acquiring 4 contiguous slices of data with each gantry rotation; systems with 8 data acquisition units (and more) are currently in development. The principal advantages offered by these systems are increased scanning speed and the ability to obtain volumetric data in high resolution. These features enable imaging with enhanced contrast concentration, decreased contrast load, decreased respiratory and cardiac motion artifact, and multiplanar and 3-dimensional reconstruction capabilities. Herein we first review the technical aspects of multidetector spiral CT scanning. The arrangement and various combinations of the detector rows are discussed. Key scanning variables, including collimation (slice thickness), pitch (the rate of table travel per gantry rotation divided by the beam collimation), and gantry speed, are briefly addressed in the context of their interrelationships. Comparison is made with single-detector-row systems to emphasize the superior scanning speed and resolution. We then discuss the various clinical applications of multidetector spiral CT, including CT pulmonary angiography, CT aortography, virtual bronchoscopy, and multiplanar and 3-dimensional reconstructions. *Key words: multidetector-row spiral computed tomography, MDSCT, CT, multiplanar reconstruction, 3-dimensional reconstruction, pulmonary angiography, aortography.* [Respir Care 2001;46(9):912–921]

Introduction

In the late 1980s, Siemens Medical Systems introduced the first helical (spiral) computed tomography (CT) scanner for clinical applications. It is characterized by the capability to transport the patient through the gantry while volumetric data are simultaneously acquired through a continuous series of x-ray tube rotations. In these single slice systems, the x-ray photons are directed at the patient using a desired thickness (or *collimation*) and are received by a single-row detector array. By eliminating the relatively time-consuming stepwise patient positioning (the so-called "stop-and-shoot" method) associated with conventional CT scanners, helical CT technology greatly reduces scanning time and improves the speed at which a volume of interest can be imaged with satisfactory quality (known as volume of coverage speed).

Though substantially improved in scanning efficiency and patient throughput, the volume coverage performance

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of single-section CT is limited by its maximum pitch, which is defined as the rate of table travel (in mm) per gantry rotation divided by the beam collimation (also known as slice thickness, in mm). To increase volume coverage speed in these systems, either the table travel speed, pitch, or collimation must be increased. Increasing table travel speed results in unsatisfactory image quality because of translation motion, whereas increasing collimation decreases spatial resolution in the longitudinal (*z*) axis of the patient. Although the volume imaged can be increased by more rapid gantry rotation, gantry speed is limited.

Spiral CT scanners use a continuously rotating gantry and continuous movement of the table and patient in order to acquire data continuously and volumetrically during the scan sequence.[1-3] Most currently available spiral scanners use a single row of *x*-ray detectors that acquire data from a tissue thickness determined by the width of the *x*-ray beam collimator (eg, 1 mm to 10 mm). The narrower the collimation, the higher the spatial resolution of the scan produced.

Single-detector-row spiral CT scanners generally have a gantry rotation speed of 0.8–1 second and table advancement per rotation of up to twice the *x*-ray beam collimation. Using a collimation of 5 mm and a pitch of 2 for a 25 cm adult thorax, assuming a tube rotation time of 1 second, a typical spiral scan requires 25 gantry rotations, or 20–25 seconds to complete. The duration of scanning is particularly important in chest imaging, as it is necessary for the patient to suspend respiration during the scan sequence if optimal images are to be obtained. Most patients can suspend respiration 20–25 seconds, and this scan duration is considered appropriate for most thoracic CT protocols. The thinnest collimation reasonably possible for a single-breath-hold scan is 5 mm. The use of thinner collimation (eg, 3 mm) in order to achieve better spatial resolution (ie, thinner slices), as is used for the diagnosis of pulmonary embolism, requires that the extent of the examination be limited to a portion of the thorax, or more than one breath must be used for imaging.

Multidetector-Row Spiral Computed Tomography

In 1992, the first spiral CT scanner employing 2 detector rows was introduced. Subsequently, several manufacturers introduced spiral CT scanners with multiple detector arrays capable of acquiring 4 simultaneous slices. These systems are characterized by multiple parallel rows of detector elements, as thin as 1 mm, that encircle the patient and that can be combined in various ways to yield 4 contiguous slices for each gantry rotation. In addition to the quadruple increase in volumetric data acquisition, some of these systems also have an increased gantry rotation speed of 0.5 second, further increasing volume coverage, and scanners able to image 8 levels or more simultaneously are currently under development.

Although current 4-slice spiral CT scanners have 4 data acquisition channels, they have more than 4 rows of detectors. This allows for scanning with various slice thicknesses. For example, one scanner system employs 16 detector rows, each 1.25 mm wide, arranged side-by-side along the axis of gantry rotation (Fig. 1). These rows can be grouped in various combinations to generate 4 slices with thicknesses of 1.25 mm (1 detector row for each slice), 2.5 mm (2 detector rows grouped together for each slice), 3.75 mm (3 detectors each), and 5 mm (4 detectors each). Because of simultaneous data acquisition from the different detectors, table advancement is rapid during scanning. A pitch of 6 relative to scan thickness is commonly used. For example, using 1.25 mm detectors, a pitch of 6, and a gantry rotation time of 0.5 second, the table travels 15 mm per second, allowing the entire thorax to be imaged in about 17 seconds with high-resolution technique. Using a scan thickness of 5 mm, a scan of the thorax would require slightly more than 4 seconds. When scanners capable of obtaining 8 simultaneous images become available, these times will be further reduced.

Advantages of Multidetector-Row Computed Tomography

The advantages of multidetector-row spiral CT (MDSCT) scanners in thoracic imaging relate primarily to their speed and volumetric data acquisition. The speed of MDSCT enables the infusion of contrast agent at a more rapid rate than with conventional spiral CT and allows both optimal opacification of intrathoracic vasculature and a reduction of the amount of contrast agent the patient receives.

Furthermore, because of the rapidity of scanning, high-resolution breath-hold volumetric imaging of the thorax is possible. Volumetric imaging makes possible both multiplanar and 3-dimensional image reconstruction techniques. In addition, a unique aspect of multidetector scanning is that the scan data can be reconstructed in various slice thicknesses after a single scan of the patient, by retrospectively grouping the data from detector rows in different ways.

Multiplanar Reconstruction

The ability of MDSCT to image the entire thorax during suspended respiration with longitudinal axis resolution of approximately 1 mm results in a nearly isotropic data set, which can be viewed in any plane without a substantial reduction in anatomic detail.[4] Most workstations currently used to view CT are capable of rapidly reconstructing sagittal and coronal images from the transaxial data. Such

images can be valuable in assessing a variety of thoracic abnormalities, particularly the mediastinal vasculature and airways.

Three-Dimensional Reconstruction

Although time-consuming and not as easily performed as multiplanar reconstruction, various 3-dimensional reconstruction techniques can be used, providing views of the imaged volume from different perspectives.[4,5] Four volumetric reconstruction techniques are generally employed with multidetector spiral CT: (1) shaded surface display, (2) maximum (or minimum) intensity projections, (3) curved planar reformations, and (4) volume rendering. Regardless of which 3-dimensional rendering technique is employed, it is imperative to view the unedited transaxial sections.

Shaded surface display renders volumes by reducing the image data to a binary set based on a predefined threshold value. Contiguous pixels above the threshold are modeled as a single 3-dimensional structure. The computer then generates an imaginary source of illumination to depict surface reflections, which are then displayed in the image gray scale.[6] Shaded surface displays also can be made with multiple threshold levels to enable representation of structures with varied attenuation.[7] Shaded surface display reconstruction is particularly good at displaying complex 3-dimensional anatomy, although the majority of information regarding relative x-ray attenuation values of different structures is lost. This method is used most often in identifying airway and vascular lesions.

Maximum intensity projection or minimum intensity projection images are generated by projecting rays through the volumetric data in any given direction. The maximum (or minimum) value encountered by each ray is encoded in a 2-dimensional projectional display.[8] Maximum intensity projection images represent the densest pixels encountered by the ray within a slab of contiguous high-resolution images, whereas minimum intensity projection images show the least dense pixels. In the thorax, maximum intensity projections have been used primarily for projection angiography. They may also be valuable in the diagnosis of nodular lung disease. Maximum intensity projection images increase the detection of small lung nodules and can be helpful in showing their anatomic distribution.[9–11] Small lung nodules are more easily distinguished from vessels on maximum intensity projection images than on routine transaxial CT. Minimum intensity projection images are of particular value in identifying airways and low-attenuation lung disease such as emphysema.[9]

Curved planar reformation represents a single-voxel-thick tomographic section prescribed by drawing a curve on either an axial section, reformatted section, surface display, or maximum intensity projection, which is then extended through the entire data set. Although it may appear similar to a simple oblique, sagittal, or coronal reconstructed image, it represents a curved plane. Curved planar reformations are particularly valuable for showing the lumen of a vessel or airway. It is important to keep in mind that curved planar reformations are operator-dependent and inaccurate curve drawing can falsely simulate lesions that are not present or can obscure true abnormalities.

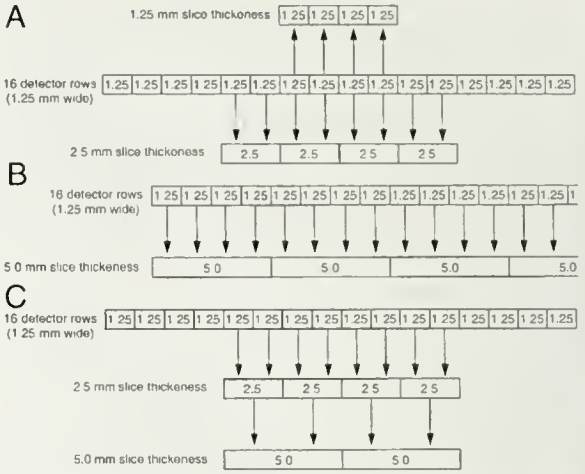

Fig. 1. Geometry of detectors in the General Electric Lightspeed QX/i quad-section multidetector-row spiral computed tomography scanner (GE Medical Systems, Milwaukee, Wisconsin). Sixteen 1.25 mm wide detector rows are arranged along the longitudinal axis of the patient. The elements can be combined into groups of 1–4 to provide scans of various thickness. A: To acquire four 1.25 mm sections, only the central 4 detectors are used. To obtain four 2.5 mm slices, the central 8 units are grouped into 4 pairs. B: All 16 detector units are activated when four 5.0 mm slices are needed. C: With the acquisition of volumetric data, retrospective reconstruction can be performed. Here, 2.5 mm thick data are reconstructed into 5 mm slices.

Volume rendering is a technique in which tissue types are assigned color, transparency, and refractive index values, depending on the information desired from the data set.[4,12] The volume rendering can be generated from within the data set, providing the viewer with a perspective from within the image. An example is virtual bronchoscopy.[13–17]

Clinical Applications of Multidetector Spiral Computed Tomography

The emergence of MDSCT scanners has fundamentally altered the manner in which CT of the thorax is performed and interpreted. Examples of the important clinical uses of MDSCT in current radiologic practice include CT pulmonary angiography, CT aortography, airway imaging, and the use of multiplanar and maximum and minimum intensity projection reconstruction in the detection of lung nodules and the diagnosis of diffuse lung disease.

Fig. 2. Computed tomography pulmonary angiography. A: Postcontrast transaxial multidetector-row spiral computed tomography (MD-SCT) (window width 450 HU [Hounsfield units], window level 50 HU, scan thickness 1.25 mm) depicts an acute pulmonary embolus (arrow) in a right lower lobe segmental artery. B: Sagittal reconstruction of the same study shows the extent of the right lower lobe pulmonary embolus (arrow). The predisposing factor, a large right hilar bronchogenic carcinoma (Ca), is also seen. C: Coronal reconstruction shows the hilar carcinoma (Ca) with mediastinal invasion.

Computed Tomography Pulmonary Angiography

The development of spiral CT scanners enabled the development of CT pulmonary angiography for the diagnosis of pulmonary embolism (Fig. 2). Using single-detector-row spiral scanners with a collimation of 3 mm and a pitch of 2, acceptable sensitivity and specificity values of about 90% have been reported for the diagnosis of pulmonary embolism,[18–25] although the accuracy of this technique has proven to be limited in the diagnosis of subsegmental emboli.[18–20,26,27]

With the development of multidetector-row scanners, high-resolution CT of the pulmonary vasculature is now possible during suspended respiration. Using 1.25 mm detectors, a pitch of 6, and a gantry rotation time of 0.5 second for CT pulmonary angiography, high-resolution images of the entire pulmonary vascular bed can be obtained in approximately 17 seconds. This reduces image degradation from patient respiratory motion and also maximizes the contrast bolus. Although the accuracy of MD-SCT in diagnosing pulmonary embolism has not been assessed, there is no doubt that its accuracy is substantially better than that of single-detector-row spiral CT. Multiplanar reformations may prove valuable.[28]

Furthermore, with multidetector-row CT, the entire thorax is usually imaged, whereas only 10–12 cm of the thorax encompassing the major pulmonary arteries are usually imaged using a single-detector-row spiral CT scanner. By offering a detailed view of the entire thorax, cardiopulmonary conditions that mimic pulmonary embolism

Fig. 3. Computed tomography aortography. A: Postcontrast transaxial multidetector-row spiral computed tomography (MDSCT) (window width 450 HU [Hounsfield units], window level 50 HU, scan thickness 2.5 mm) in a patient with type A aortic dissection. At the level of the thoracic inlet, the intimal flap is seen extending into the right subclavian artery (black arrow) and right common carotid artery (white arrow). A large right pleural effusion is also seen. B: More inferiorly, on a scan through the cranial aspect of the aortic arch, the intimal flap is seen in the innominate artery (white arrow) and the aortic arch (black arrow). The false lumen of the brachiocephalic artery is hypodense (asterisk), indicating delayed perfusion. C: At the level of the atrioventricular valves, an intimal flap is seen in the descending thoracic aorta. The true (black arrow) and false (white arrow) lumina are well illustrated. Slow flow in the false lumen is evidenced by the diminished contrast opacification. The compressed true lumen shows normal opacification. D: Sagittal reconstructed image of the aorta shows the celiac artery (arrow) arising from the true lumen of the aortic dissection, as is characteristic. The false lumen (asterisk) is posterior. Because of the rapid scanning, the entire aorta can be imaged. E: A maximum intensity projection image shows the intimal flap in the abdominal aorta. The true (white arrow) and false (black arrow) lumina are well delineated. The left renal artery (small arrow) arises from the false lumen. The reduced contrast opacification of the false lumen of the aorta, the left renal artery, and the left kidney is consistent with slow flow. The right kidney, supplied by the true lumen, shows normal enhancement.

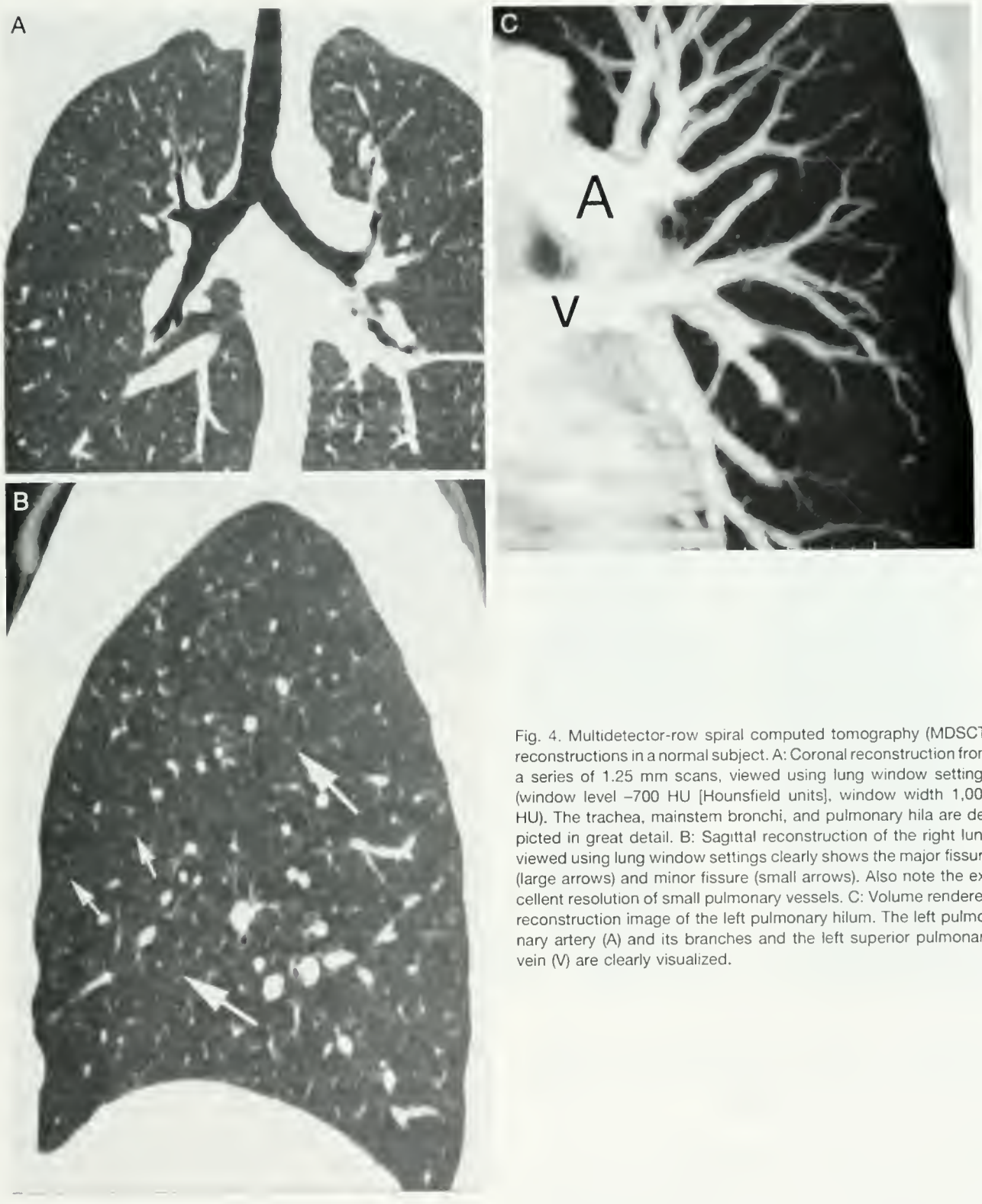

Fig. 4. Multidetector-row spiral computed tomography (MDSCT) reconstructions in a normal subject. A: Coronal reconstruction from a series of 1.25 mm scans, viewed using lung window settings (window level –700 HU [Hounsfield units], window width 1,000 HU). The trachea, mainstem bronchi, and pulmonary hila are depicted in great detail. B: Sagittal reconstruction of the right lung viewed using lung window settings clearly shows the major fissure (large arrows) and minor fissure (small arrows). Also note the excellent resolution of small pulmonary vessels. C: Volume rendered reconstruction image of the left pulmonary hilum. The left pulmonary artery (A) and its branches and the left superior pulmonary vein (V) are clearly visualized.

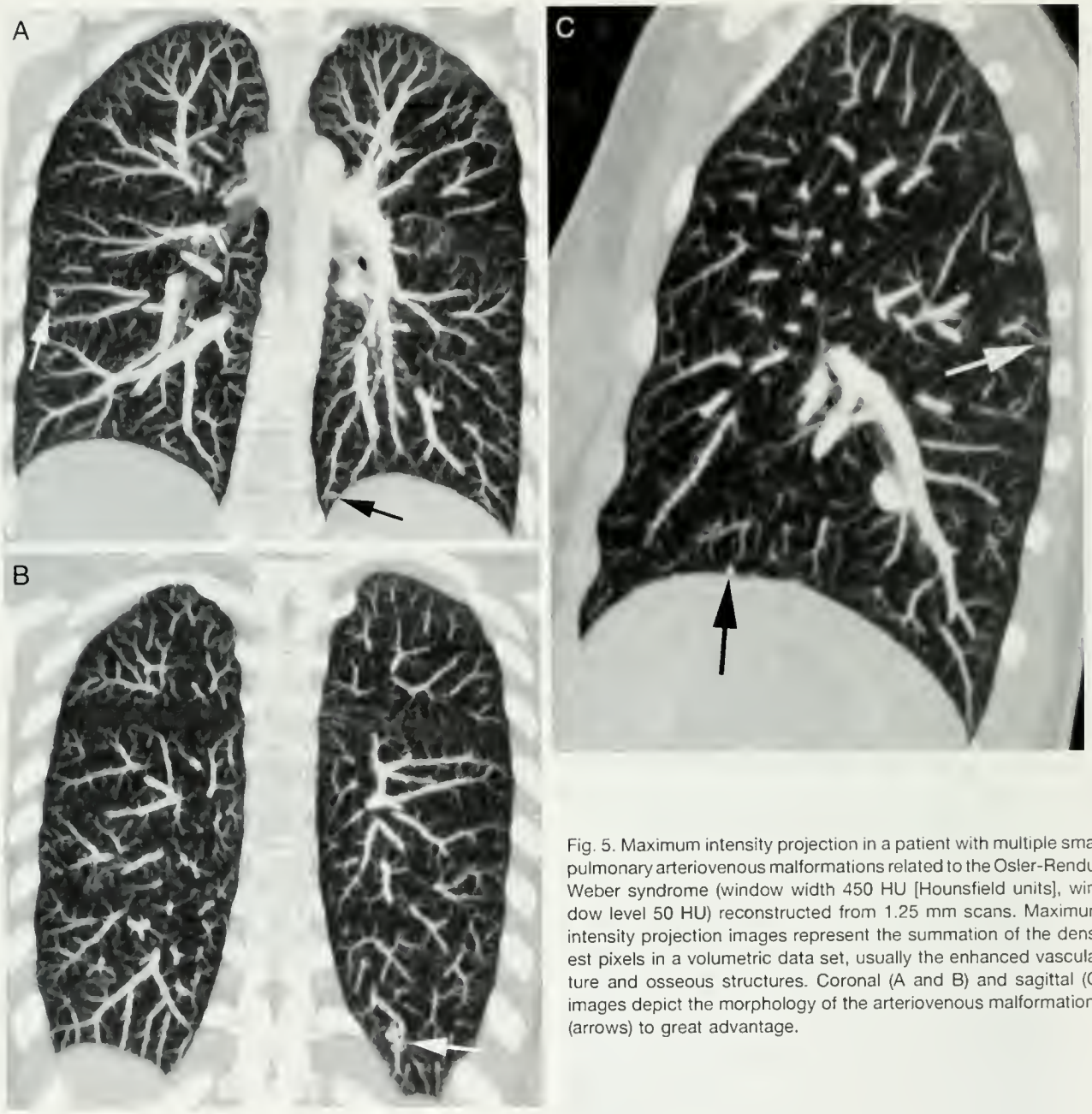

Fig. 5. Maximum intensity projection in a patient with multiple small pulmonary arteriovenous malformations related to the Osler-Rendu-Weber syndrome (window width 450 HU [Hounsfield units], window level 50 HU) reconstructed from 1.25 mm scans. Maximum intensity projection images represent the summation of the densest pixels in a volumetric data set, usually the enhanced vasculature and osseous structures. Coronal (A and B) and sagittal (C) images depict the morphology of the arteriovenous malformations (arrows) to great advantage.

clinically may also be discovered. Common such findings include pulmonary edema, pneumonia, atelectasis, pleural effusion, and aortic abnormalities.

Computed Tomography Aortography

Imaging of the aorta is an important use of spiral CT,[29-31] and imaging of various acquired aortic abnormalities (including traumatic aortic injury, aortic dissection, penetrating atherosclerotic ulcer, and aortic aneurysm) has benefited greatly from the increased volumetric scanning speed of MDSCT.[32] With a collimation of 2.5 mm and pitch of 6, the aorta can be easily scanned in its entirety (ie, from the aortic arch to its bifurcation in the abdomen) during optimal contrast concentration. By imaging during early arterial phase, it is also possible to determine perfusion of the aorta and its branches. This capability is important in such applications as aortic dissection studies, where differential contrast opacification allows the evaluation of perfusion to the true and false lumina, as well as the major mesenteric and renal branches (Fig. 3). To further assess the aortic abnormality, the acquisition of high-resolution

Fig. 6. Multidetector-row spiral computed tomography (MDSCT) scan of a patient with centrilobular and paraseptal emphysema. A: Transaxial 1.25 mm section showing multiple lucencies characteristic of centrilobular and paraseptal emphysema (window level −700 HU [Hounsfield units], window width 1,000 HU). B: Axial reconstruction at the same level as Figure 6A, using a minimum intensity projection technique accentuates the attenuation difference between normal and emphysematous lung parenchyma. The emphysema is clearly shown to be predominant on the right side. On a minimum intensity projection image, pulmonary vessels disappear and parenchyma is seen to best advantage. C: Coronal reconstruction using minimum intensity projection technique in the same patient. Predominance of emphysema in the right upper lobe (arrows) is clearly seen. Identifying the distribution of emphysema may be valuable in planning surgical treatment.

volumetric data allows multiplanar and 3-dimensional reconstruction, which allows detailed evaluation of the location and extent of aortic disease.

Detection of Lung Nodules and Diagnosis of Lung Disease

Interpretation of the high-resolution volumetric data set resulting from a MDSCT scan necessitates the use of a workstation rather than film and view box. This is not only because of the large number of slices obtained for a chest scan (approximately 200) but also the need to view them in different ways and with different reconstruction algorithms (Fig. 4). For example, because of the thin, high-resolution images obtained with MDSCT, small lung nodules may be difficult to distinguish from vessels seen in cross section. This problem can be overcome by the reconstruction of thicker slices from the volumetric data set or by the use of maximum intensity projection images, on which branching vessels and nodules are easily distinguished.

Maximum intensity projection, by showing the densest structures in a volume to best advantage, allows multiplanar reconstruction to elucidate vascular abnormalities such as pulmonary emboli and pulmonary arteriovenous malformations (Fig. 5). Similarly, as indicated above, maximum intensity projection images may be valuable in the diagnosis of diffuse lung diseases.

Minimum intensity projection, on the other hand, improves visualization of low-attenuation lung lesions by selecting for the pixels of lowest attenuation (ie, those containing air). This technique has proven valuable in assessing subtle variations in lung attenuation, such as in the case of mild emphysema (Fig. 6) and subtle air trapping (Fig. 7).

Airway Imaging

By acquiring isotropic volumetric data in high resolution, MDSCT allows multiplanar and 3-dimensional reconstruction. These techniques have been used to advantage in imaging the airways, particularly in patients with airway stenoses and endobronchial lesions.[33–37] Three-dimensional airway imaging from an internal perspective (ie, virtual bronchoscopy) is an example.[38,39] The clinical usefulness of these techniques is yet to be evaluated.[40]

Summary

Since its introduction in 1992, multidetector spiral CT has revolutionized thoracic imaging. The most important progress has been in CT pulmonary angiography, CT aortography, virtual bronchoscopy, and high-resolution isotropic reconstruction. Current state-of-the-art systems employ 4 detector units, allowing volumetric registration of data with resolution ranging as high as 1.25 mm. Coupled

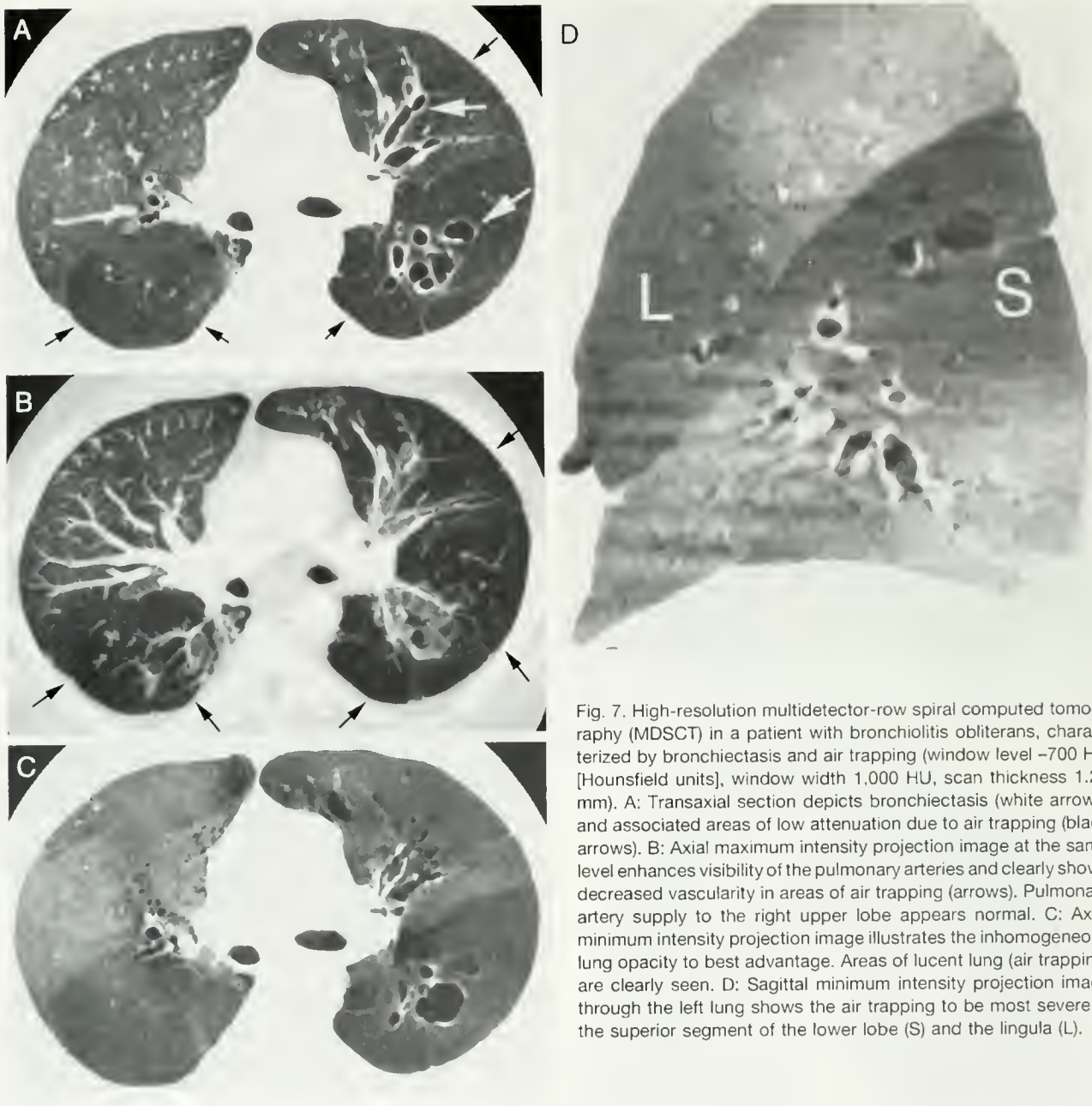

Fig. 7. High-resolution multidetector-row spiral computed tomography (MDSCT) in a patient with bronchiolitis obliterans, characterized by bronchiectasis and air trapping (window level –700 HU [Hounsfield units], window width 1,000 HU, scan thickness 1.25 mm). A: Transaxial section depicts bronchiectasis (white arrows) and associated areas of low attenuation due to air trapping (black arrows). B: Axial maximum intensity projection image at the same level enhances visibility of the pulmonary arteries and clearly shows decreased vascularity in areas of air trapping (arrows). Pulmonary artery supply to the right upper lobe appears normal. C: Axial minimum intensity projection image illustrates the inhomogeneous lung opacity to best advantage. Areas of lucent lung (air trapping) are clearly seen. D: Sagittal minimum intensity projection image through the left lung shows the air trapping to be most severe in the superior segment of the lower lobe (S) and the lingula (L).

with the doubling of gantry rotation speed to 0.5 seconds, it is now possible to acquire isotropic imaging data with increased speed and resolution. The numerous advantages of multidetector CT include reduced volumes of contrast, improved contrast opacification, increased scanning speed, less patient motion artifact, and improved quality of multiplanar and 3-dimensional reconstructions. These features are particularly valuable in the imaging of intrathoracic vasculature, where scanning speed is critical to ensuring optimal contrast opacification. Meanwhile, volumetric data acquisition allows retrospective reconstruction in exquisite detail. The various reconstruction algorithms potentiate multiplanar and 3-dimensional evaluation of intrathoracic vasculature, airways, and lung parenchyma. With the development of 8-detector systems currently in progress, it is foreseeable that these advantages will be further augmented in the near future.

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Magnetic Resonance Imaging of the Chest

Charles S White MD

Introduction
Magnetic Resonance Imaging Techniques
Thoracic Arteries and Veins
Magnetic Resonance Imaging of Specific Thoracic Regions
Newer Thoracic Magnetic Resonance Imaging Techniques
Summary

Thoracic magnetic resonance imaging (MRI) has recently undergone important advances, and newer applications could expand the role of thoracic MRI. Existing and developing MRI techniques are described and compared to other imaging techniques with regard to imaging various thoracic regions, structures, and diseases. After an initial discussion of MRI techniques, the role of thoracic MRI in evaluation of the thoracic arteries and veins is described. The next section focuses on specific anatomic regions; namely, the lung, mediastinum, pleural space, thoracic inlet, and diaphragm. The final section reviews some novel techniques that may improve our ability to visualize the pulmonary parenchyma and mediastinum. *Key words: thoracic imaging, magnetic resonance imaging, thoracic vessels, lung cancer, mediastinum, pleura, thoracic inlet, diaphragm, MR ventilation.* [Respir Care 2001;46(9):922–931]

Introduction

[1]Magnetic resonance imaging (MRI) of the chest has not received the attention that has been devoted to many other parts of the body. Nevertheless, substantial progress has been made both in understanding the application of current MRI techniques to the thorax and in developing newer methods to investigate the thorax.

This overview of the state of chest MRI is organized into several sections. After an initial discussion of MRI techniques, the role of thoracic MRI in evaluation of the thoracic arteries and veins is described. The next section focuses on specific anatomic regions; namely, the lung, mediastinum, pleural space, thoracic inlet, and diaphragm. The final section reviews some novel techniques that may improve our ability to visualize the pulmonary parenchyma and mediastinum.

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Magnetic Resonance Imaging Techniques

Spin-echo techniques remain in wide use for the evaluation of the thorax by MRI and produce dark blood images.[1] For imaging adjacent to the heart, electrocardiogram-triggering should be used to reduce phase-encode artifacts. With triggering, T1-weighted images are acquired by setting the repetition time equal to one R-to-R interval. Because the R-R interval is determined by the patient's heart rate, for patients with slow heart rates (long R-R interval) images may not be as T1-weighted as in other parts of the body. The echo time is typically set at 20 ms. More recently the use of double inversion recovery imaging has permitted acquisition of T1-weighted images during a breath-hold.

T2-weighted images, which in the thorax are used to characterize soft tissue abnormalities, are obtained as multiple R-R intervals, such that the repetition time exceeds 2,000 ms. The echo time is usually prescribed as 100 ms. Recently, the development of gated fast spin-echo techniques has allowed acquisition of T2-weighted dark blood images much more rapidly. The brightness of thoracic masses on T1- and T2-weighted images often allows some tissue characterization of the masses.

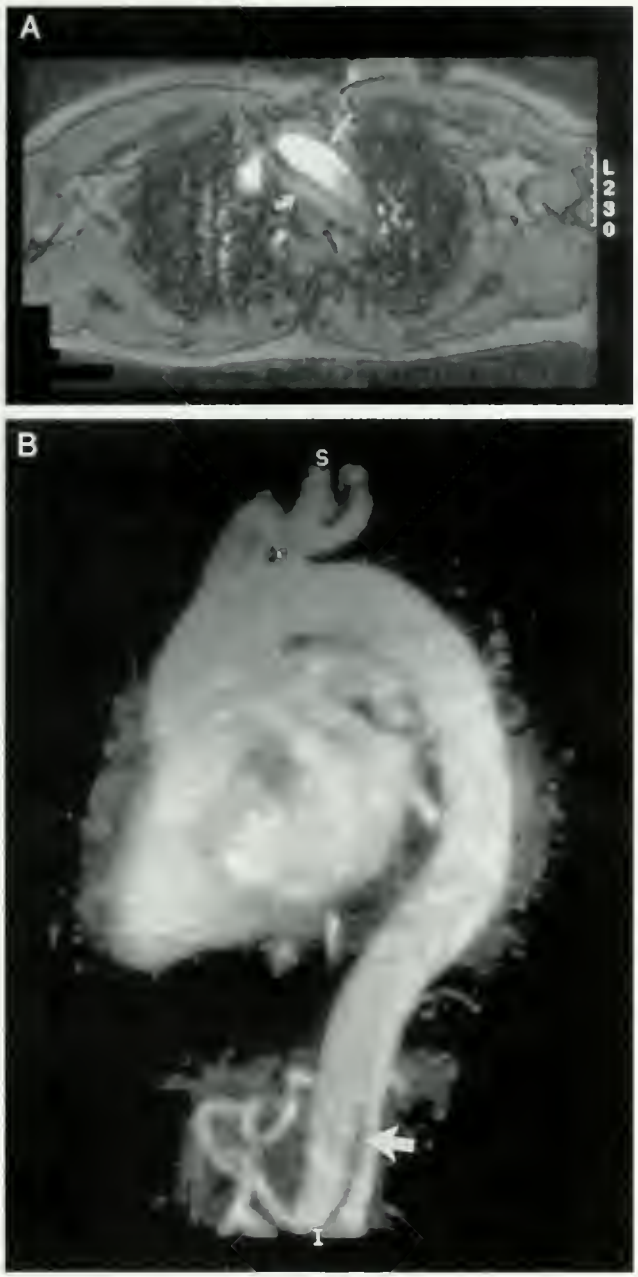


Fig. 1. A 33-year-old man with aortic dissection. A: Gradient-echo magnetic resonance image through the aortic arch shows an intimal flap separating the true (straight arrow) and false (curved arrow) lumina. B: On contrast-enhanced magnetic resonance angiography (MRA), the intimal flap (arrow) is identified in the descending thoracic aorta.

Bright blood imaging is essential for assessment of vascular structures.[2] This technique employs gradient-echo imaging and flow-compensation to produce high signal intensity in flowing blood. The images can be gated and placed into a cine loop that allows assessment of vascular motion. Because gradient-echo sequences are obtained very rapidly, bright-blood imaging can be acquired in a breath-

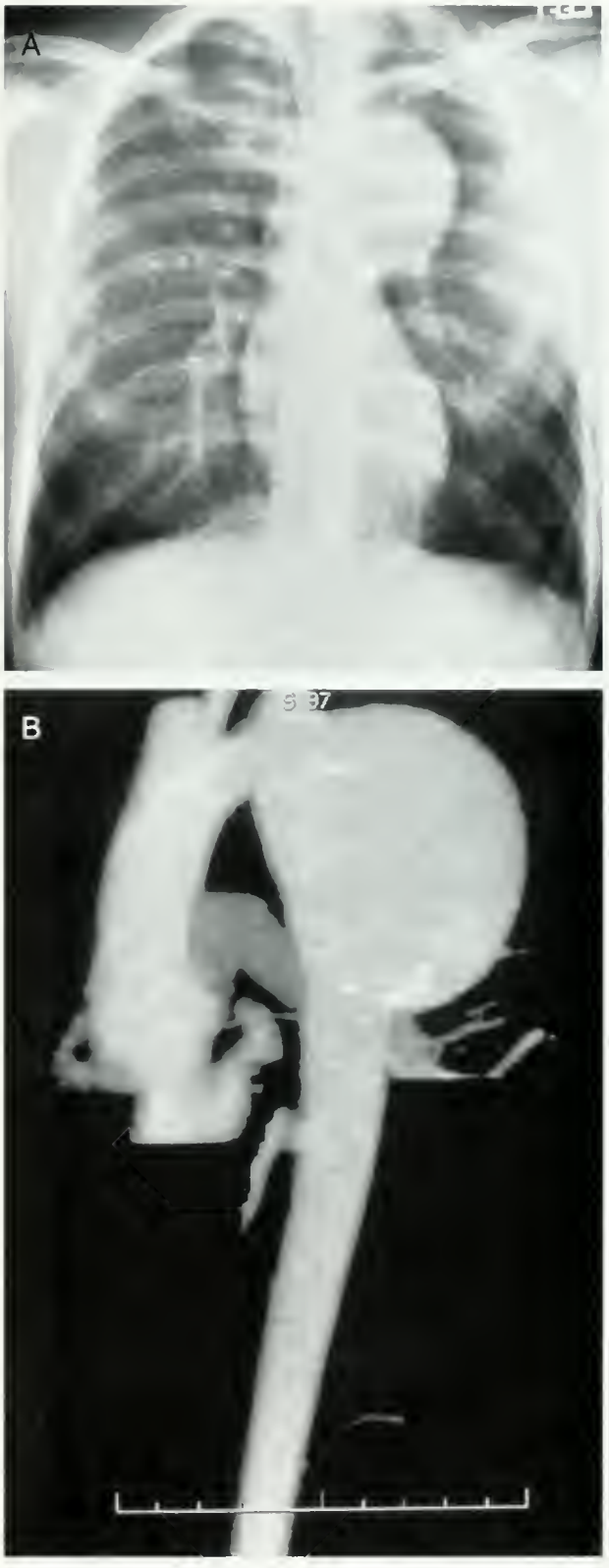


Fig. 2. A 28-year-old man with a mycotic aneurysm. A: Chest radiograph shows a focal mass extending from the left superior mediastinum. B: On contrast-enhanced magnetic resonance angiography (MRA), a large saccular aneurysm projects from the aorta just distal to the takeoff of the left subclavian artery.

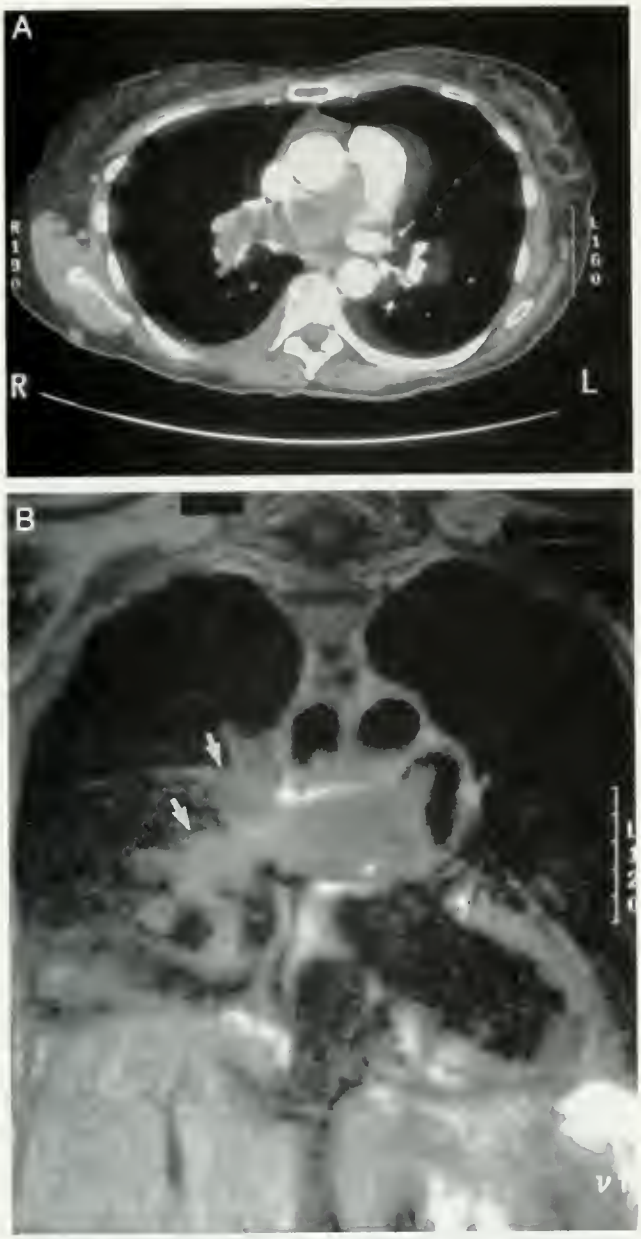


Fig. 3. A 60-year-old woman initially thought to have pulmonary embolism. A: Contrast-enhanced computed tomography scan shows a large filling defect within the main and right pulmonary arteries. B: On a coronal T1-weighted spin echo magnetic resonance image, the branch pulmonary arteries are also involved (arrows). This lesion did not resolve with anticoagulants and proved to be an angiosarcoma.

hold. Recently developed steady-state precession sequences (true fast imaging with steady-state precession) permit a higher contrast-to-noise ratio between the blood pool and surrounding tissues.

Contrast enhancement is usually performed with gadolinium chelate and plays a considerable role in evaluating thoracic disease by MRI.[3] For chest lesions, the enhancement pattern may allow tissue characterization of the abnormality. For vascular disease, the use of contrast material increases the signal-to-noise ratio and permits generation of magnetic resonance angiography (MRA), which can be displayed in a 3-dimensional format.

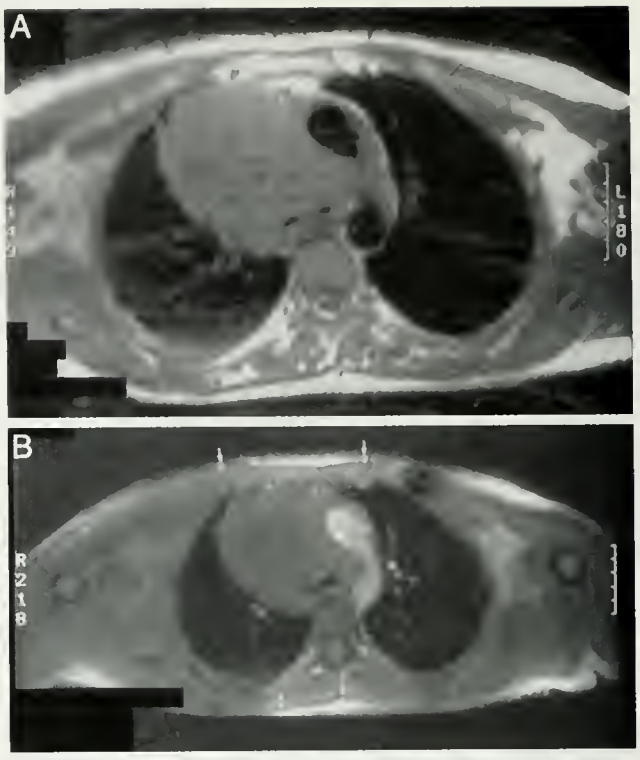


Fig. 4. A 49-year-old man with an invasive thymoma and superior vena cava (SVC) obstruction. A: Axial T1-weighted spin echo magnetic resonance image shows a large anterior mediastinal mass adjacent to the aorta. There is no flow void in the expected position of the SVC. B: Gradient-echo magnetic resonance image reveals the mass and absence of flow within the SVC. Using this sequence, collateral vessels in the chest wall are well visualized (arrowheads).

A torso-array coil is usually sufficient for imaging of the chest. For structures adjacent to the heart, a dedicated cardiac coil can be used. Respiratory compensation is advisable to decrease artifacts caused by ghosting. This can be accomplished by the use of a bellows or with MRI pulses that track the motion of the diaphragm, combined with an algorithm that accepts only images obtained with the diaphragm in a central position.

Thoracic Arteries and Veins

MRI is one of the best techniques to assess the aorta. It is more versatile than computed tomography (CT) because images can be acquired directly in any plane, whereas CT is restricted to the axial plane, with off-axial reconstruction required. Moreover, with MRI, both dark and bright blood images can be obtained and contrast use is optional.

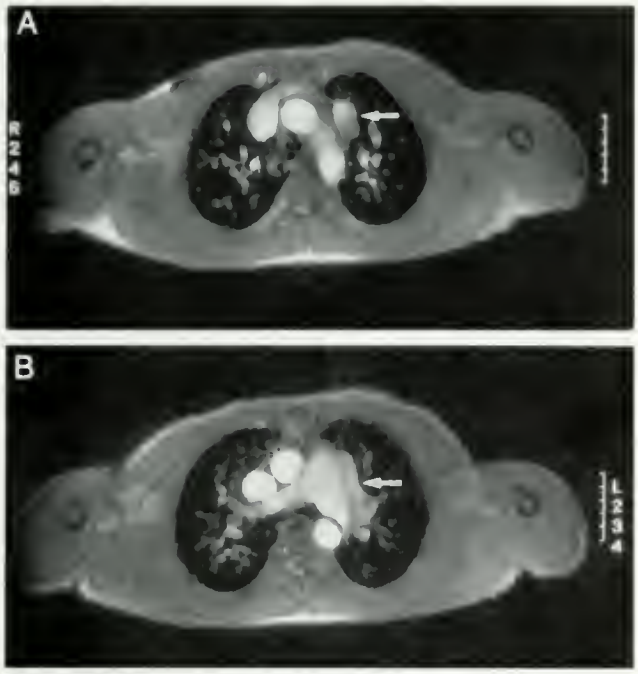


Fig. 5. A 30-year-old man with partial anomalous pulmonary venous return from the left upper lobe. A: Gradient-echo magnetic resonance image shows an anomalous structure (vertical vein) lateral to the aortic arch (arrow). B: At a more inferior level, the venous return from the left upper lobe can be seen entering the vertical vein (arrow).

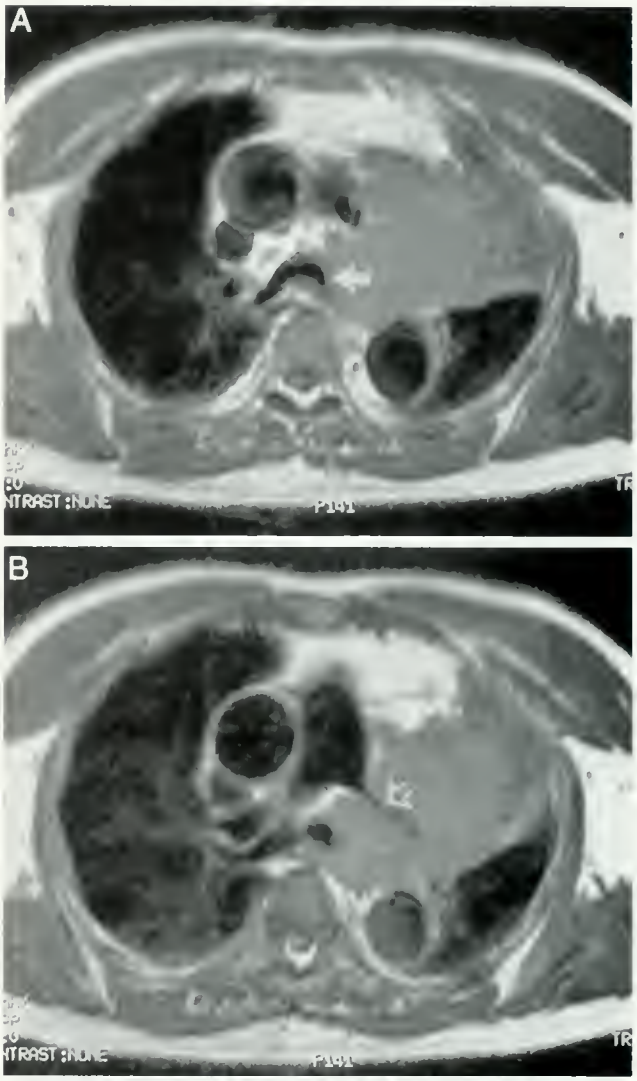


Fig. 6. A 66-year-old-man with invasive lung cancer. A and B: Contiguous axial T1-weighted spin echo magnetic resonance images show a large left upper lobe mass invading the mediastinum and encasing the left main bronchus (solid arrow) and left pulmonary artery (open arrow).

With CT, contrast injection is required for optimal assessment. Disadvantages of MRI are the longer setup time, the increased likelihood of claustrophobia, the greater expense, and less availability of scanners.

MRI is valuable to assess acquired aortic diseases such as aortic dissection and aneurysm.[4] Aortic dissection is caused by separation of a part of the wall of the aorta, with entry of blood into the wall. An intimal flap, representing the dissected portion of the wall, divides the true and false (intramural) channels (Fig. 1). MRI using dark and bright blood imaging identifies and localizes the intimal flap. MR angiography can show the relationship of the flap to the great vessels.[5] If the flap involves the ascending aorta or arch (Type A), surgery is indicated. If the flap is restricted to the descending aorta (Type B), medical therapy is preferred.

Aortic aneurysm (an abnormal dilatation of the aorta that can be caused by atherosclerosis, connective tissue disease, trauma, or infection) is also well depicted on MRI (Fig. 2).[6] The location, size, and amount of clot within the aneurysm can be observed. Aneurysms larger than 5 cm are at risk for rupture and are usually referred for surgical repair.

MRI is useful to evaluate congenital abnormalities of the aorta. Aortic coarctation is a constriction of the aorta, typically located just distal to the subclavian artery. This area is well visualized by echocardiography in infants but is less accessible in adults. MRI provides an effective noninvasive method to assess the location and extent of constriction, the gradient across the coarctation, and the amount of collateral vessel formation.[7] Other congenital abnormalities of the aorta include an aberrant right subclavian artery, right aortic arch, and double aortic arch. These entities may form vascular rings that compress the esophagus or trachea, causing symptoms of dysphagia or stridor. MRI accurately delineates the location and type of anomaly and the compressive effects of the anomalous vessels.[8]

MRI has also been applied to imaging of the pulmonary arteries. An ultra-fast, gradient echo, 3-dimensional gad-

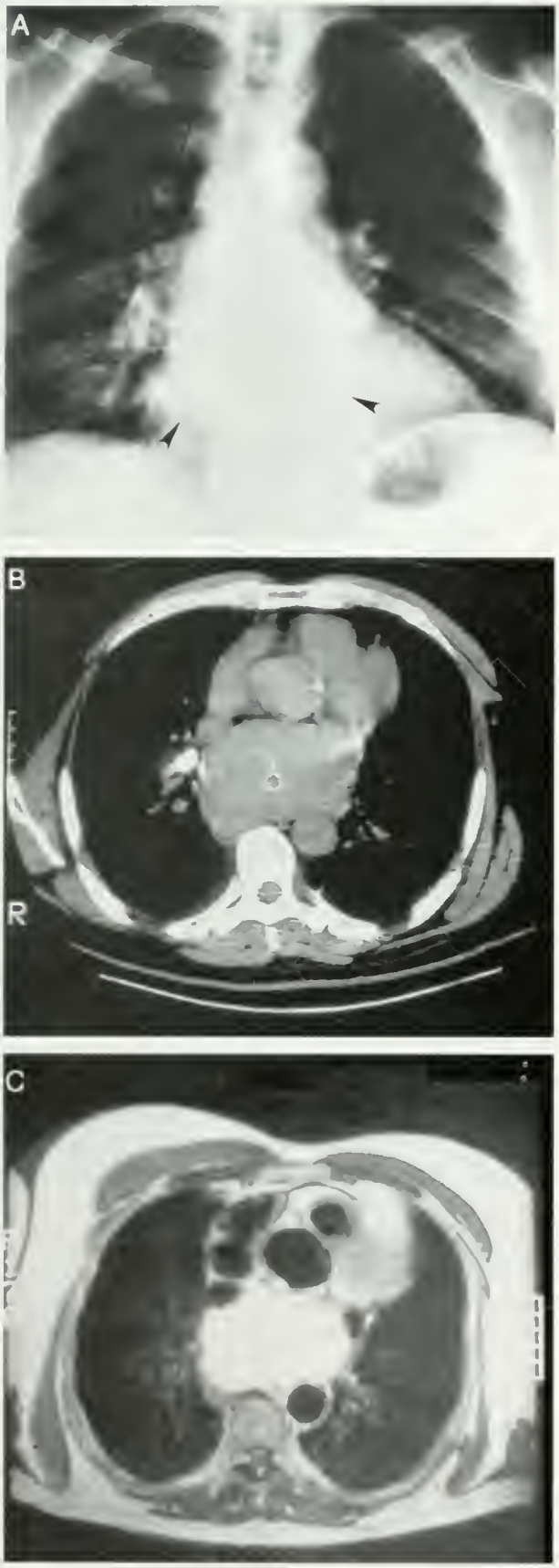
Fig. 7. A 37-year-old woman with a benign cystic teratoma. A: Chest radiograph shows a mediastinal mass adjacent to the right heart border. B: Computed tomography scan shows that the mass is in the anterior mediastinum and is of low density. C: On axial T1-weighted spin echo magnetic resonance image, the lesion contains areas of high signal intensity (arrow), indicating fatty content.

olinium enhanced sequence (MRA) has been used to diagnose pulmonary thromboembolic disease and other abnormalities of the pulmonary arteries.[9] Pulmonary MRA provides accurate assessment of clot in the lobar and segmental pulmonary arteries but is less sensitive in diagnosing subsegmental clot. With the state of current technology, multislice CT scan appears superior for imaging small pulmonary emboli, and pulmonary MRA can be considered an alternative in patients with renal failure or contrast allergies. Pulmonary MRI and MRA are occasionally used to assess primary neoplasms of the pulmonary arteries and congenital pulmonary anomalies such as pulmonary sling (Fig. 3).[10]

Venous anatomy is well depicted on MRI. The most important acquired venous abnormality is superior vena cava (SVC) obstruction, which is due to either an extrinsic compression by tumor (usually lung cancer or lymphoma) or an intrinsic process such as catheter-induced thrombosis. MRI is valuable to assess the cause, location, and extent of compression or obstruction.[11] Bright blood imaging is useful to delineate the presence of collateral vessels (Fig. 4). MRI can also be employed to define congenital venous variants. Abnormalities such as a left SVC, azygos continuation of the inferior vena cava, and anomalies of pulmonary venous return are also well depicted on MRI (Fig. 5).[12]

Magnetic Resonance Imaging of Specific Thoracic Regions

Lung cancer remains the leading cause of death from cancer and has a dismal 5-year survival rate.[13] The tumor typically is found initially on chest radiographs, and CT is the principle cross-sectional technique used to stage lung cancer. In general, MRI is approximately as accurate as CT to evaluate the extent of primary tumor and mediastinal lymph nodes.[14] However, because of its higher cost and lesser availability, it serves mainly as a problem-solving tool when CT results are equivocal. MRI is frequently used with patients who have apical sulcus (Pancoast) tumor. These tumors often grow through the lung apex and may affect the brachial plexus, subclavian vessels, and vertebral bodies. The vertical orientation of the lung apex and superb soft-tissue contrast resolution of MRI make this technique valuable for evaluating tumors in this area.[15] MRI may also be worthwhile to evaluate suspected vascular invasion by tumor because of its ability to perform bright and dark blood imaging (Fig. 6).[11] MRI is occasionally used to assess indeterminate nodules or pulmonary lesions other than lung cancer, although positron emission scanning has largely supplanted MRI for this indication. MRI may be useful to detect subtle nodules near the hilum, because of the anatomic complexity of this



region, particularly if a contrast-enhanced CT cannot be performed.

Mediastinal masses are usually categorized by their location in the mediastinum. Thymoma and its variants, germ cell tumors such as teratoma and lymphoma, typically occur in the anterior mediastinum.[16] Duplication cysts, esophageal lesions, and lymphadenopathy are common in the middle mediastinum, and neurogenic tumors are the most common posterior mediastinal lesions.[17] CT is the mainstay of diagnosis and delineates the location and size of the lesion. The presence of fat, calcium, or contrast enhancement may permit greater tissue specificity. MRI sometimes serves in a complementary role because it may confirm the tissue characteristics of a lesion identified on CT.[18] Mediastinal fat is bright on T1-weighted images, and most mediastinal abnormalities appear as lower signal intensity masses within the fat. On T2-weighted images, mediastinal lesions show variable signal intensity. Certain signal patterns indicate specific lesions. Teratomas often contain areas of fat that are manifested as areas of high signal intensity within the mass on T1-weighted images, which are identical to mediastinal and subcutaneous fat (Fig. 7).[19] Cysts typically show very bright signal intensity on T2-weighted images.[20] They may also show high signal intensity on T1-weighted images if they contain hemorrhage or protein (Fig. 8). On T2-weighted images, neurogenic tumors often show high signal intensity peripherally and low signal intensity centrally, termed the "target" sign.[21]

Pleural disease is usually evaluated on CT. MRI is typically reserved for equivocal cases. A transudative pleural effusion usually shows low signal intensity on T1-weighted images and high signal intensity on T2-weighted images. Exudative or hemorrhagic effusions often show high signal intensity on T1-weighted images. Loculated effusions may be better defined on MRI than on CT.[22,23] Solid tumors are well depicted by MRI. MRI may be slightly more accurate than CT to detect chest wall invasion by lung cancer.[14]

Mesothelioma is a primary malignant tumor of the pleura and has a strong association with asbestos exposure. The prognosis is grim and complete surgical resection is the only hope for cure. An extrapleural pneumonectomy is the curative technique of choice, but success requires that the tissues beyond the parietal pleura be free of tumor. CT is the standard imaging technique to assess the extent of mesothelioma, but MRI may have an advan-

Fig. 8. A 56-year-old man with a hemorrhagic bronchogenic cyst. A: Chest radiograph shows infracarinal mass lesion (arrowheads). B: Computed tomography scan filmed on soft tissue windows reveals a homogeneous lesion of soft tissue density. C: On an axial T1-weighted spin echo magnetic resonance image, a lesion of uniformly very high signal intensity is present, consistent with a hemorrhagic bronchogenic cyst.

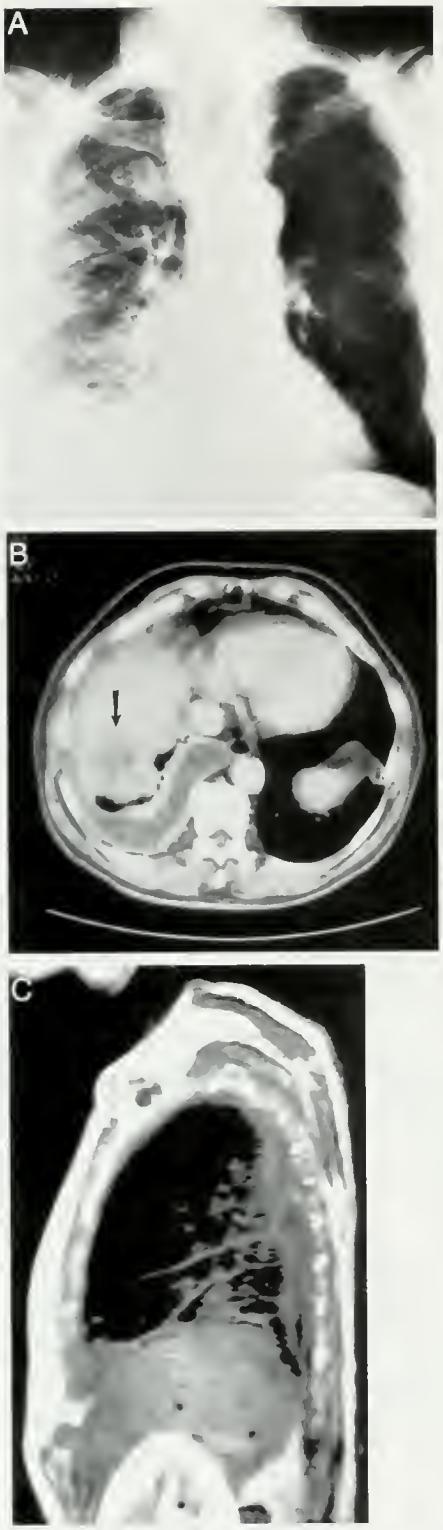


Fig. 9. A 65-year-old man with malignant mesothelioma. A: Chest radiograph shows diffusely thickened pleura, with contraction of the right hemithorax. B: Computed tomography scan shows a pleural rind with a lesion in the liver (arrow). C: On sagittal T1-weighted spin echo magnetic resonance imaging, it is apparent that the liver lesion is due to direct extension of tumor through the diaphragm (arrow).

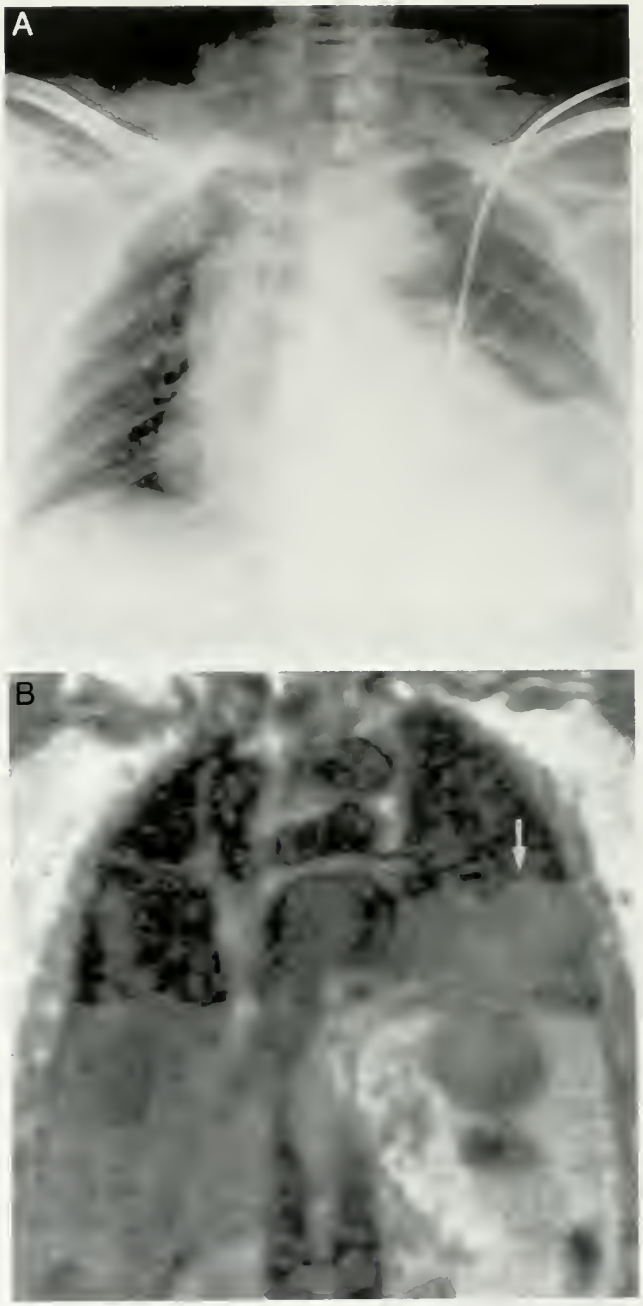


Fig. 10. A 50-year-old man with a diaphragmatic hernia after trauma. A: Chest radiograph shows apparent elevation of the left hemidiaphragm. B: Coronal T1-weighted spin echo magnetic resonance image shows that abdominal contents have herniated through the diaphragm into the left chest (arrow).

tage in showing subtle invasion of the chest wall, mediastinum, or diaphragm (Fig. 9).[24]

The thoracic inlet is an area of complex anatomy bridging the neck and thorax.[25] The brachial plexus courses through this region and may be involved by trauma or tumor. As noted above, CT is usually acquired first in patients with Pancoast tumor, and MRI furthers defines the

Fig. 11. A 72-year-old woman with a peridiaphragmatic lesion. A: Chest radiograph shows a lesion that projects in the right cardiophrenic angle (arrow). B: On a coronal T1-weighted spin echo magnetic resonance image, the lesion is posteriorly located and is entirely above the diaphragm. C: More anteriorly, a vessel (arrow) extends into the lesion from the aorta, consistent with a pulmonary sequestration.

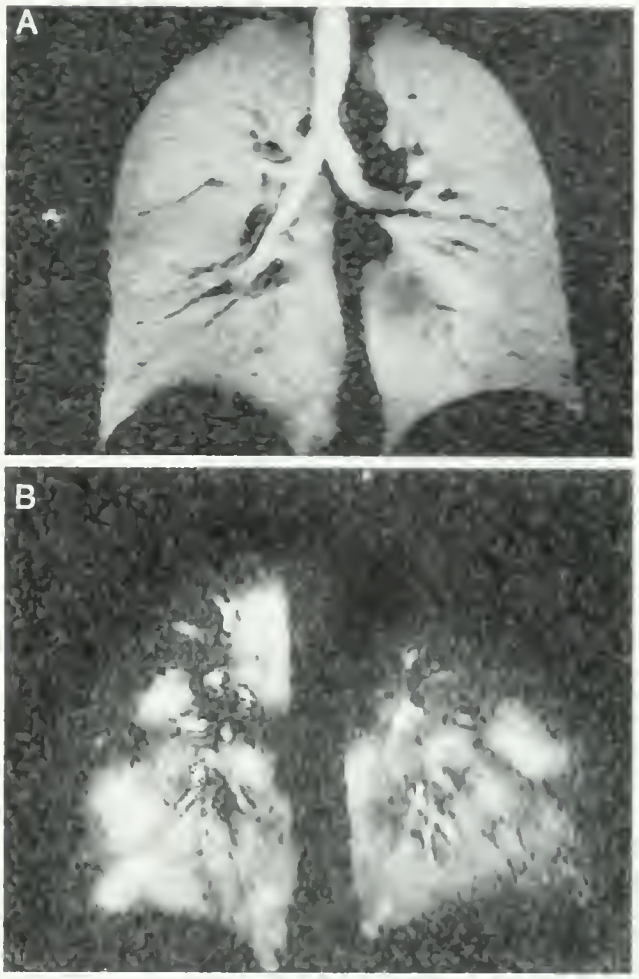


Fig. 12. Magnetic resonance ventilation. A: Coronal He-3-enhanced magnetic resonance image in a healthy volunteer shows distribution of gas to all lung regions. B: Coronal He-3-enhanced magnetic resonance image in a patient with cystic fibrosis shows multiple bilateral upper lobe defects representing areas of absent ventilation. (Cases courtesy of H Page McAdams MD, Department of Radiology, Duke University Medical Center, Durham, North Carolina).

extent of the lesion.[15] In other patients with symptoms related to the thoracic inlet and lower neck, MRI is often the primary imaging technique and shows hematoma, pseudomeningocele from nerve root avulsion, a mass lesion, or enlarged lymph nodes. A brachial neuritis may manifest as enlargement of brachial plexus components, with hyperintensity on T2-weighted images.[26,27]

The thyroid and parathyroid glands also occupy the thoracic inlet. Most thyroid lesions visualized on imaging are multinodular goiters and, pathologically, are adenomas. Nearly all goiters have a connection to the thyroid. Many extend inferiorly anterior to the thymus, but 20% or more protrude more posteriorly adjacent to the trachea. On MRI, the normal thyroid shows intermediate signal intensity on T1-weighted images and higher signal intensity on T2-weighted images. Thyroid goiters usually have heterogeneous signal characteristics.[28] They often contain colloid or hemorrhagic cysts that show high signal intensity on

T1-weighted images. Although MRI is a sensitive technique in the diagnosis of thyroid goiter, it usually cannot distinguish between benign and malignant thyroid lesions. Thus, it is used less frequently than CT or sonography. However, it may prove useful to assess recurrent thyroid malignancy.[29]

The parathyroid glands are found adjacent to the thyroid gland. In patients with primary hyperparathyroidism, preoperative imaging is infrequently obtained because surgical excision is successful in over 90% of patients. In the 10% of the patients with ectopic parathyroid glands in whom a primary surgical approach fails, most glands are located in the tracheoesophageal groove or anterior mediastinum. Imaging may assist in locating such glands, allowing successful re-operation. On MRI, parathyroid adenomas are of intermediate signal intensity on T1-weighted images and very high signal intensity on T2-weighted images.[30] A combination of MRI and technetium–99m-methoxyisobutyl-isonitrile (Tc–MIBI) radionuclide imaging offers the best approach to locating ectopic parathyroid glands, with sensitivity and specificity of 89% and 95%, respectively.[31]

MRI is useful to evaluate traumatic and nontraumatic processes in the peridiaphragmatic region. Trauma injury to the diaphragm may prove a difficult diagnostic challenge. Chest radiographic findings such as elevation of the left hemidiaphragm are useful, but findings are often nonspecific.[32] CT scan may show diaphragmatic injury but the axial imaging plane may cause interpretation difficulties. Thus, off-axial reconstructions are often necessary. MRI is valuable because of its high soft tissue contrast resolution and its ability to directly acquire images in any plane. Generally, T1-weighted images are obtained through the affected diaphragm in both sagittal and coronal planes (Fig. 10). Breath-hold T1-weighted gradient images may also prove useful. With these sequences, the diaphragm appears as a low signal intensity curvilinear structure separating abdominal and mediastinal structures. The diaphragm is difficult to identify adjacent to normal lung but is visible next to consolidated lung, which is common in traumatized patients. Diaphragm injury is visualized as a discontinuity of the normal curvilinear structure, with herniation of abdominal contents into the chest. In a study of 16 patients at our institution, MRI proved valuable when CT findings were equivocal.[33]

MRI also depicts nontraumatic peridiaphragmatic processes well but is less widely used for these indications. Occasionally, hiatal or paraesophageal hernias are incidentally found on MRI. Congenital hernias, such as anterior Morgagni and posterior Bochdalek hernias, can be evaluated by MRI if results of other imaging studies are equivocal. The multiplanar capability of MRI permits imaging along the long axis of the hernia. MRI may also be useful to determine on which side of the diaphragm a juxtadiaphragmatic process is located, particularly if the precise location is uncertain from other studies (Fig. 11).[34,35]

Newer Thoracic Magnetic Resonance Imaging Techniques

Of recently described MRI techniques, the most promising appears to be MR ventilation. MR ventilation was developed to overcome limitations inherent in imaging lung parenchyma, such that only minimal signal is produced. These limitations are caused by several factors, including low water density in the lungs resulting in few available protons for MRI, motion artifacts due to breathing and other physiologic processes, and susceptibility artifacts.[36]

MR ventilation can be performed with either hyperpolarized gas or 100% molecular oxygen (oxygen-enhanced imaging) The hyperpolarized technique uses either He-3 or Xe-129.[37] The MR imager must be modified with a broadband radiofrequency system and specialized radiofrequency coil. Gradient-echo images are usually obtained using a single breath-hold after inhalation of polarized gas. A complete set of coronal images can be acquired in less than 15 seconds.[38]

Oxygen-enhanced imaging is a recently proposed technique for MR ventilation and is based on the premise that an ultra-high concentration of dissolved oxygen in the arterial blood can lead to substantially enhanced lung signal.[39]

MR ventilation offers better spatial resolution than scintigraphic lung perfusion and obviates ionizing radiation. The technique is very sensitive in showing perfusion defects caused by parenchymal lung disease such as cystic fibrosis, bronchiolitis obliterans related to lung transplantation, and emphysema (Fig. 12).[38] The specificity of the technique is less certain and its clinical utility remains to be defined.

Another area of investigation is the use of contrast agents to distinguish benign from malignant mediastinal lymph nodes, termed MR lymphography. This technique requires injection of superparamagnetic ultra-small iron oxide particles with imaging before and 24–48 hours after injection. Macrophages in the lymph node ingest the iron oxide particles, leading to reduced signal intensity in normal lymph nodes on T2-weighted images. Malignant nodes have fewer macrophages and thus have less avid uptake of the particles, leading to higher residual signal intensity on T2-weighted images.[40] A recent preliminary study in 30 patients showed a sensitivity of 100% and specificity of 80% in distinguishing benign from malignant mediastinal lymph nodes. Although the data are promising, further work is necessary to validate this technique.[41]

Summary

MRI of the thorax is a powerful tool that has witnessed explosive development in the last decade. Nevertheless, it is mainly used clinically when the results of other techniques are equivocal. Newer applications such as those described above may yet expand the role of thoracic MRI.

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Thoracic Sonography

Christopher S Krejci MD, Erin J Trent RDCS, and Theodore Dubinsky MD

Introduction
Technique
Pleural Diseases
  Pneumothorax
  Pleural Effusion, Hemothorax, and Empyema
  Pleural Masses
Pulmonary Disease
  Consolidated Lung/Pneumonia and Pulmonary Abscess
  Pulmonary Embolism
  Lung and Mediastinal Masses
Diseases of the Aorta
  Aortic Dissection
  Aortic Intramural Hematoma
  Penetrating Aortic Ulcers
Summary

Sonography has inherent limitations for thoracic imaging because sound waves are reflected by bone and air space (such as in lung parenchyma). However, sonography is less expensive and more convenient than computed tomography (CT) or magnetic resonance imaging (MRI); it provides immediate information with real-time imaging; and it can provide information not available from a standard radiograph. This review describes the utility and limitations of sonography and compares sonography to radiography, CT, and MRI with regard to diagnosing pleural, pulmonary, and aortic diseases, including pneumothorax, pleural effusions and masses, hemothorax, empyema, consolidated lung, pneumonia, pulmonary abscess, pulmonary embolism, mediastinal masses, aortic dissection, aortic intramural hematoma, and penetrating aortic ulcers. *Key words: thoracic sonography, ultrasonography, computed tomography, magnetic resonance imaging.* [Respir Care 2001;46(9):932–939]

Introduction

Imaging of the chest is performed using multiple modalities, each of which provides valuable information to the diagnosis and evaluation of cardiopulmonary disease. Though the chest radiograph is the cornerstone of thoracic imaging evaluation, advanced techniques such as computed tomography (CT), magnetic resonance imaging (MRI), and ultrasonography provide useful information that cannot be ascertained by the standard radiograph.

Presently in the United States, ultrasonography is underutilized for imaging chest disease because of the general availability of CT, the ease of interpreting CT images, and the inherent limitations of ultrasound. However, ultrasound offers several important advantages over CT and MRI for the evaluation of chest disease. Ultrasound is portable and flexible, and sonographic images are immediately accessible for evaluation of critically ill patients needing rapid bedside examination. Evaluation of vascularity and perfusion is possible by use of color doppler. Patients can be easily evaluated in multiple positions without the need of

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bed transfers needed for CT or MRI, and there are no restrictions in imaging planes. Ultrasonography is relatively inexpensive, compared to CT and MRI, and there is no ionizing radiation exposure. Last, unlike CT and MRI, the real-time nature of ultrasound allows superior evaluation of moving structures such as the heart, and, in combination with color flow and duplex imaging, physiologic information regarding wall motion and valve patency can be obtained.

The 2 key limiting factors prohibiting sonographic evaluation of the chest are based on the physical limitations of the ultrasound beam. First, air limits progression of the sound waves by reflecting the beam at the interface between the aerated lung parenchyma and consolidated lung or the overlying pleural surface. Second, the bones of the thorax absorb the sound waves, preventing propagation to the underlying tissues and thus limiting the ultrasound window. This review briefly examines the uses, indications, benefits, and limitations of chest sonography.[1–4]

Technique

Advances in sonographic technology have increased the ability to evaluate chest disease. Presently, high-frequency (5–7.5 MHz) linear array transducers using small parts algorithms are used for evaluating chest wall masses and adenopathy. Pleura and lung are generally best imaged by the use of a 3.5–5 MHz sector or phased array probe with a small footprint that facilitates positioning between ribs. Transesophageal echosonography is used primarily for the evaluation of cardiac disease; however, mediastinal disease, especially aortic disease, can be well evaluated and followed with the multiplanar transesophageal approach, with 3.5–7 MHz frequencies. Further advances in technology and development of hand-held portable scanners have increased the ability to rapidly examine patients in the trauma setting as resuscitation is ongoing, without hindering the resuscitation procedure.

Pleural Diseases

Pneumothorax

Pneumothoraces commonly occur spontaneously after blunt or penetrating chest trauma as a complication of mechanical ventilation, or as a complication of procedures such as line placement, thoracentesis, or biopsy. Chest radiography is usually easily obtainable and diagnostic; however, small to moderate pneumothoraces may be missed because of the limitations of anteroposterior portable chest radiograph. Early detection of pneumothorax may prevent progression into life-threatening pneumothoraces.

Using ultrasonography, real-time respiratory movements can be evaluated with observation of the hyperechoic visceral pleura interface and the "comet tail" reverberation artifact produced by aerated lung at this interface. With a pneumothorax, air within the pleural space hinders propagation of the sound waves and thereby prevents the comet tail artifacts. Another useful sign of pneumothorax is the loss of normal lung sliding (breath-related movement of the visceral pleura) or the appearance of the "lung point," a specific described sign of pneumothorax.[5–10]

Pleural Effusion, Hemothorax, and Empyema

The pleura is seen on ultrasound as an echogenic layer measuring up to 2 mm thick. The pleural layers in a normal patient may not be easily discerned; however, with increase in fluid between the layers or disease of the pleura itself, ultrasound can differentiate the visceral from the parietal pleura.

Increased pleural fluid occurs secondary to increased hydrostatic forces (congestive heart failure), decreased oncotic pressure (hypoproteinemia), decreased lymphatic drainage (tumor or fibrosis), increased permeability of the capillaries (inflammation or malignancy).[11,12] Effusions occur as either transudates (which are often bilateral and most commonly due to hypoproteinemia, congestive heart failure, or hypothyroidism) or exudates (most commonly associated with malignancy, bacterial pneumonia, or connective tissue disorders). On lateral chest or decubitus radiographs as little as 5 mL of pleural fluid can be identified; however, frontal chest radiographs especially supine portable chest radiographs, are not nearly as sensitive. Ultrasound is more sensitive at detecting smaller effusions (as little as 3–5 mL) than upright frontal radiographs, provides useful information on the nature of the fluid, and allows guidance for thoracentesis or placement of pleural drains. Pleural hemorrhage, empyema, pleura-based masses, and hemothorax can also be evaluated with the use of ultrasound.

By ultrasound, a pleural effusion appears as a hypoechoic zone that changes shape with respiratory movements (Fig. 1). Pleural fluid can be differentiated from pericardial fluid by its relationship to the descending thoracic aorta. Pleural fluid is visualized posterior to the descending aorta, whereas pericardial fluid is seen anterior to the descending aorta. An area of hyperechoic, consolidated lung is often seen with larger pleural effusions. These areas of lung are often mobile within the fluid, and on real-time imaging consolidated lung can be seen moving within the effusion. Internal echoes within the fluid are usually associated with exudates and represent protein, fibrin, or cells and are frequently associated with septations and loculation. Infected effusions generally follow an evolutionary course beginning with pleuritis identified by

Fig. 1. Sagittal sonogram of right-sided serous pleural effusion. The hypoechoic fluid (black) outlines two areas (arrow and L) of atelectatic lung.

pleural thickening with an interrupted pleural line and increased vascularity identified on doppler imaging. An early exudative stage then appears, with a hypoechoic or heterogeneous effusion. As a more complicated effusion evolves, fibrin begins to deposit and loculations begin to form (Fig. 2). Finally, in the empyema stage, thick fibrin deposits form pleural peels.[13,14]

Hemothorax is often seen in patients with underlying lung or pleural malignancy and also in patients sustaining chest trauma. Complications of hemothorax include empyema formation, calcified fibrothorax, and constrictive pleural fibrosis. Echogenic collections are seen on ultrasound[15] and differentiation from other exudates, chylothorax, or empyema is not possible without thoracentesis. As with the detection of pneumothoraces, portable trauma ultrasound of the pleura during resuscitation of trauma patients is gaining acceptance as a sensitive, specific, and rapid complement to portable chest radiography.[11,16]

As stated above, ultrasound is useful in confirming the presence of and evaluating the pleural fluid. Further advantages of ultrasound offer guidance for thoracentesis. Ultrasound-guided thoracentesis has lower complication rates than CT guidance and nonguided approaches, with a reported pneumothorax incidence of 0–3%. It is associated with lower costs and easier accessibility than CT, while offering the advantages of real-time visualization of the effusion, lungs, and vascular structures, improving the efficacy of tube position by placement into specific loculations, with associated increases in therapeutic success (67–88% for complex collections), and allowing a multiplanar approach that requires less patient cooperation and makes guidance easier with real-time visualization of the needle tip.

Most benign sterile effusions do not require drainage unless there is associated respiratory compromise; however, empyemas, recurrent effusions, malignant effusions, and moderate to large hemothoraces frequently require drainage to avoid associated sequelae. Unexplained pneumothoraces require thoracentesis for cytologic evaluation and are frequently seen associated with undiagnosed malignancy or connective tissue disorders. Along with the placement of drainage catheters, intracavitary fibrinolytics are frequently used to dissolve fibrinous debris causing fibrous loculations and obstructing small bore drainage catheters. Malignant effusions account for nearly 50% of exudative effusions and are most frequently associated with lung, breast, and gastrointestinal carcinomas, as well as lymphoma. Most malignant effusions are free-flowing, may be large, and generally recur following drainage. For patients with life expectancies greater than one month, pleurectomy or pleurodesis is indicated.[4,5,12,13,17–21]

Pleural Masses

Pleural tumors are generally well defined solid nodular lesions located on the visceral or parietal pleura. Differentiation of small pleural effusions from pleural thickening, scar, or small nodule can be difficult; however, with color doppler images, signal can be seen within the fluid during respiratory and cardiac movements, helping differentiate these entities. Pleural thickening is seen as focal echogenicity (> 3 mm) with irregularity of the margins arising from the visceral or parietal pleura.

Pleural calcifications are commonly encountered with pleural sonography. Common causes are infection, espe-

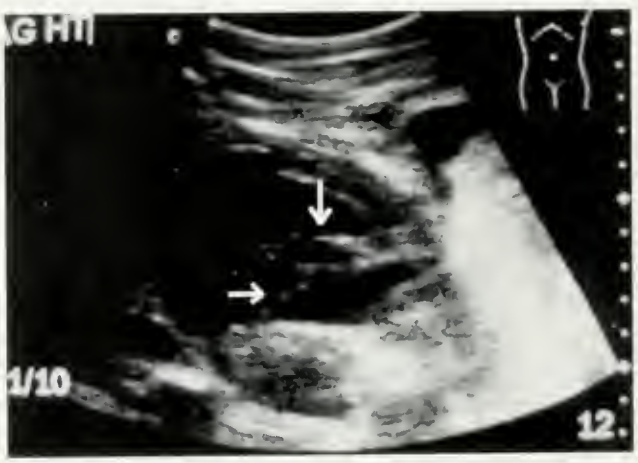

Fig. 2. Sagittal image demonstrating a complex effusion. The presence of septations (arrows) within the effusion indicates loculation that tends to occur with resolving hemothorax or empyema.

cially tuberculous, old hemothorax, and asbestos-related pneumoconiosis. Pleural plaques are frequently associated with asbestos exposure and are seen as focal areas of pleural thickening up to 10 mm and rarely extending for more than 4 rib interspaces. There is strong association with malignant mesothelioma, especially in the tobacco-smoking population. These plaques are best evaluated with CT; however, guidance for biopsy can be made by ultrasound, with the advantages previously described. Pleural metastases (bronchogenic, breast, gastrointestinal, kidney, and ovarian carcinomas) make up the frequently seen malignancies involving the pleura. Imaging of pleural metastases is not frequently seen because of their small size (usually < 1 cm); however, they can grow into large masses with heterogeneous echogenicity, may invade the chest wall, and are frequently associated with malignant pleural effusions.[5,13,20]

Pulmonary Disease

Consolidated Lung/Pneumonia and Pulmonary Abscess

Chest radiographs remain the primary diagnostic modality and are substantially more sensitive than ultrasound in the diagnosis of pneumonia. As previously discussed, ultrasound evaluation of lung parenchyma is limited by aeration of normal lung; however, ultrasound can help identify the etiology of pulmonary consolidation when the involved lung extends up to the pleural surface, and it is useful in differentiating complex pleural disease from parenchymal disease.

Early pneumonia is characterized by congested lung with hyperechoic homogenous echogenicity and irregular, bizarre shapes with blurred margins, and is frequently associated with air bronchogram (nonpulsatile linear echoes with or without comet tail reverberation artifacts) or fluid bronchogram (anechoic tubular structures corresponding to fluid-filled bronchi as a result of bronchial obstruction by secretions). Based on these findings, differentiation from pulmonary embolism/infarction and malignancy is possible, as these entities generally have segmental or round, more regular shapes and less accentuated air bronchograms. Further differentiation can be made with use of color doppler sonography. Progression of pneumonia demonstrates increased inhomogeneity of the affected lung, with increased air interface artifacts. As bacterial pneumonias progress, pulmonary abscesses can be seen on ultrasound as round or oval, mostly echogenic lesions, frequently containing air artifacts.[21]

Pulmonary Embolism

Presently, nuclear medicine scintigraphy and helical CT angiogram are the standard modalities for evaluating suspected pulmonary emboli; however, unexpected pulmonary emboli are probably a common entity contributing to morbidity. Ultrasound findings have been described, and several recent studies have indicated that ultrasonography may be beneficial in the evaluation for pulmonary embolus, especially when the other modalities are inconclusive.

Shortly after an embolic occlusion, there is infiltration of the lung interstitium, producing consolidation and providing a sonographic window. These areas are generally pleura-based and wedge-shaped. Initially the regions are hypoechoic, homogeneous, and less distinct. As the occlusion progresses to lung infarct, the border becomes more sharp and distinct, with the center becoming hyperechoic. Several studies have stated the sensitivity is between 77% and 98% and have suggested ultrasound become part of the diagnostic algorithm for evaluation of suspected pulmonary embolus. Color doppler sonography may be useful in discerning pneumonia from pulmonary infarction by identifying decreased blood flow to the affected segments.[2,21–24]

Lung and Mediastinal Masses

As with the other parenchymal manifestations, ultrasound of pulmonary masses is limited; however, sonography can be useful in further characterizing peripheral lung tumors and allows guidance for transthoracic biopsy. Ultrasound is also very useful in the characterization of peridiaphragmatic lesions, which are difficult to evaluate based on axial CT and plain chest radiograph. Ultrasound can give valuable information regarding pleural and chest wall extension of lesions (Figs. 3 and 4) and provides a useful tool in evaluation of suspected obstructing masses that cannot be clearly differentiated from pneumonitis on CT.

Ultrasound guidance is frequently used for transthoracic biopsy and is superior to CT when the lesion can be visualized. First, the examination is faster than CT and can be performed at the patient's bedside. Second, fewer complications are associated with ultrasound guidance. Third, real-time visualization is possible, allowing a higher percentage of diagnostic results because of improved targeting within the suspected lesion. Finally, a multiplanar approach allows flexibility in targeting a lesion and in compensating for difficulties with the patient, such as tachypnea, patient positioning, or immobile patients. With the use of transesophageal probes, mediastinal masses can be evaluated and biopsied for histologic diagnosis.[1,2,25–27]

Diseases of the Aorta

Ultrasonography has proven valuable in the evaluation of diseases of the aorta, such as aortic dissection and the atypical variants of dissection.[28–33] The preferred modalities for evaluation of the aorta are aortography, CT, and

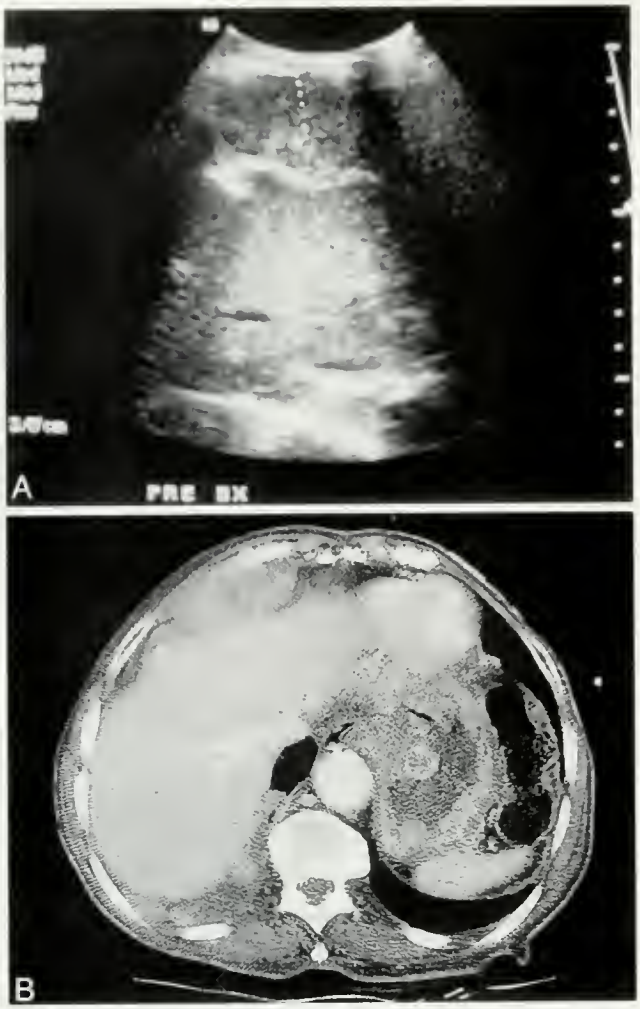

Fig. 3. Transverse ultrasound image (A) and the corresponding computed tomography image (B) of a pleural based mass. Such lesions are easily biopsied under direct ultrasound guidance.

MRI, but these are not always feasible, and all three require transporting the patient to perform the test. Aortography is the accepted standard, but it is an invasive procedure requiring a fully functioning cardiac catheterization lab. It carries risks because it is invasive, as well as the risks associated with any examination requiring contrast. MRI is beginning to be thought of as the most accurate method for aortic evaluation (nearly 100%), but is expensive, time-consuming, and requires patient immobility. Also many patients have metallic valves or implants (eg, pacemakers, defibrillators) that prohibit the use of MRI. CT is less time-consuming than MRI, but requires intravascular contrast.[28–33]

Transesophageal echocardiography has proven to be accurate and safe and can be done portably in approximately 15 minutes. It requires no intravascular access for contrast injection, and there is no delay for post-acquisition image processing. Using the multiplanar probe, transesophageal echocardiography is used to fully evaluate the descending aorta from diaphragm to arch. Evaluation of the aortic root and proximal ascending aorta is a routine part of a standard transthoracic echocardiographic examination. However, transthoracic echocardiography is inadequate for aortic evaluation beyond the proximal ascending because of overlying or adjacent air-filled structures as well as the greater penetration depth that must be obtained. Transesophageal echocardiography allows for use of a higher frequency and therefore provides better resolution than transthoracic imaging. A standard echocardiographic examination is also performed in addition to an aortic survey, which gives information on coronary involvement of the dissection as well as subsequent aortic insufficiency. Neither CT nor MRI can give information on these very important considerations when determining management of these patients.[28–30]

Aortic Dissection

The most common abnormality of the aorta is dilation. Hypertension is the most common reason for aortic dilation, but it also occurs in a wide variety of other disease states, such as atherosclerosis, post-stenotic dilation, Marfan syndrome, and other connective tissue disorders. Aneurysms (large areas of dilation) can involve the aorta at any location, and can lead to life-threatening rupture or dissection. Classic aortic dissection occurs when the intima and media of a vessel begin to separate and form another lumen between these 2 layers, called a false lumen. These false lumens have a high risk of limiting blood supply to organs by impinging on the true lumen, rupturing, and or thrombosing (Figs. 5 and 6).[28–38]

Fig. 4. A cystic chest wall mass is demonstrated on a sagittal ultrasound image. It was not clear whether this mass was invading the pleura, but on real time imaging the pleura could be seen to be moving separately from the mass.

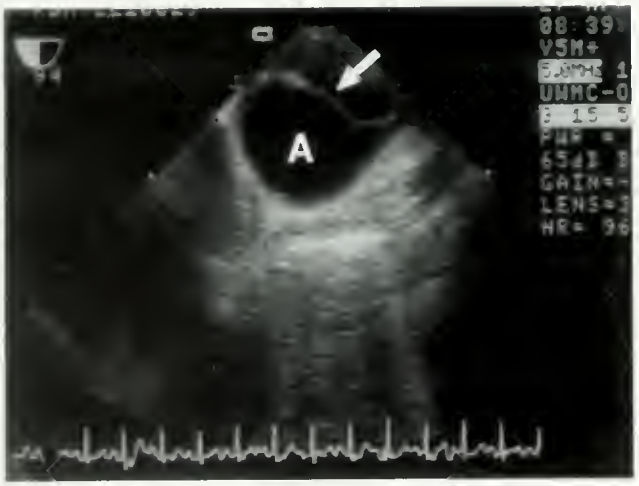

Fig. 5. Transesophageal echocardiogram transverse section of the descending thoracic aorta (A), with intimal dissection flap (arrow). (Image courtesy of University of Washington Medical Center, Department of Echocardiography.)

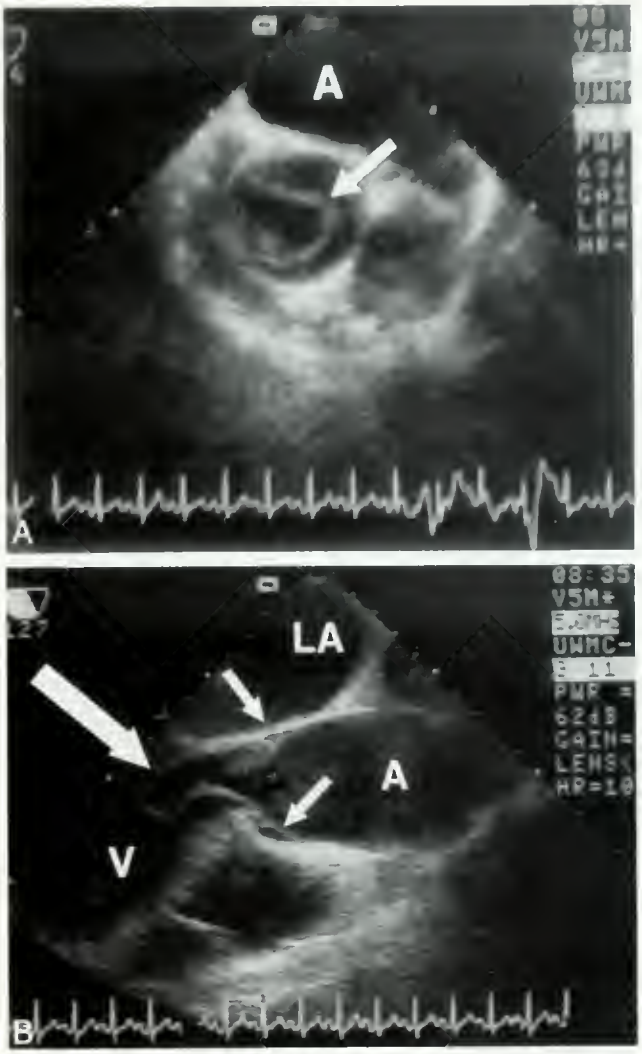

Fig. 6. A: Transesophageal echocardiogram transverse section at the level of the aortic root, showing an aortic dissection with serpiginous intimal flap with extraluminal blood within the false lumen. Arrow points to dissection flap. B: Mid-esophageal long axis transesophageal echocardiogram demonstrating prolapse of aortic dissection flap (large arrow) through the aortic valve in diastole with obstruction of valve coaptation. A = aorta. LA = left atrium. V = ventricle. Small arrows point to aortic valves.

Transesophageal echocardiography has a 97% sensitivity and a 98% specificity for detection of intimal dissection flaps.[2] Dissection flaps appear as a linear, echogenic structure within the lumen of the aorta. Ultrasound artifacts such as reverberation can cause linear echoes within the aorta that can be mistaken for an intimal flap. For this reason, to distinguish a true dissection from an echo artifact, the linear flap must be identified in more than one view, and must show motion independent from the aorta. Color flow may be seen between the false lumen and the true lumen, with turbulent flow in between. Color doppler can be used to define the entry site of the intimal tear. DeBakey's classification names the types of dissections by the location of the intimal tear (entry site) along the aorta. Type 1 originate in the ascending aorta and extend past the origin of the left subclavian artery. Type 2 are confined to the ascending aorta, and Type 3 have origins distal to the left subclavian artery.[28-38]

Aortic Intramural Hematoma

Aortic intramural hematoma is an atypical variant of classic aortic dissection, characterized by a hemorrhage of the aortic vasa vasorum into the aortic wall, which leads to a false channel created in the absence of an intimal tear. There is recent documentation of cases where aortic intramural hematoma progressed to classic aortic dissection. Because of this, there is speculation that aortic intramural hematoma may be a common intermediate step in the development of classic dissection, with a high risk of progression and/or rupture.[31,32,34,38]

Echocardiographic characteristics of aortic intramural hematoma include circular or crescentic thickening of the aortic wall, with no evidence of doppler flow within this area. This thickened wall exhibits a hypoechoic, thrombus-like echo pattern with a layered appearance. A circular lumen is maintained and echolucent areas within the thickened wall may be seen.[34,37,38]

Penetrating Aortic Ulcers

Transesophageal echocardiography provides high resolution images of the interface between the intima and the lumen of the aorta. This allows for information to be obtained about the morphology and characteristics of athero-

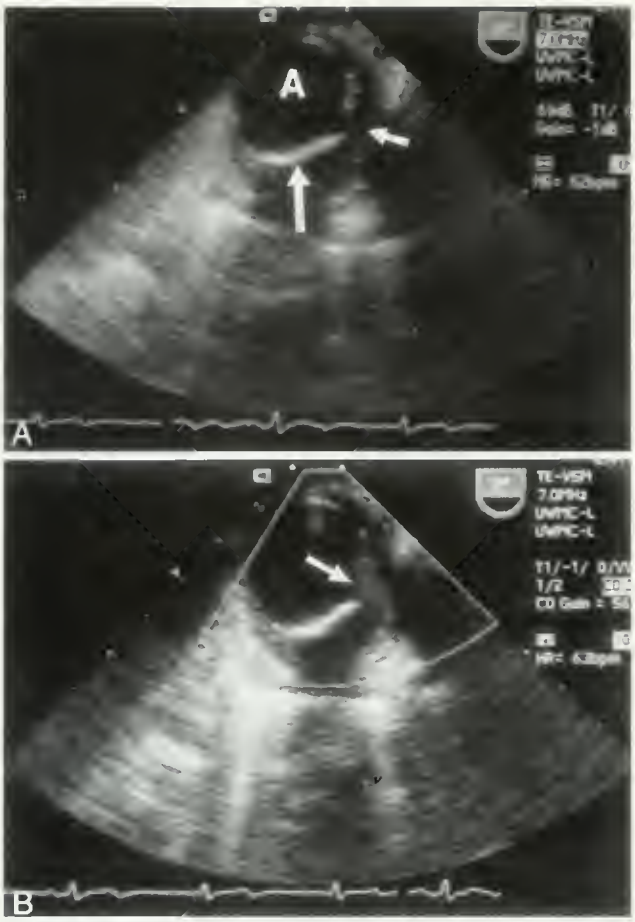

Fig. 7. A: Transesophageal echocardiogram transverse section of the descending thoracic aorta (A) with a calcified atheromatous plaque at the posterior aspect (large arrow). Posterior acoustic shadowing is demonstrated. At the lateral margin is a hypoechoic extraluminal hematoma. Small arrow points to rupture. B: Flow (arrow) from the aortic perforation into periaortic hematoma. (Images courtesy of University of Washington Medical Center, Department of Echocardiography.)

sclerotic plaques in the aorta. Transesophageal echocardiography can provide some insight when estimating the risk of systemic embolization by looking at the thickness, surface ulcerations, mobility, and presence of calcium within the plaque. This information can help guide the clinician in determining the need for anticoagulation by evaluating the complexity of the plaque. The highest risk atheromas are thick, hypoechoic, noncalcified plaques found in the aortic arch.[29,32,33,36–40]

Penetrating aortic ulcer is similar to aortic intramural hematoma in that it is also a variant of classic aortic dissection and there is no intimal tear involved. Possible complications are also similar, including rupture (Fig. 7), aneurysm, pseudoaneurysm, and dissection. Penetrating aortic ulcer may lead to aortic intramural hematoma, but the true relationship between the two is not well defined. The main distinguishing feature is that doppler flow patterns should be observed within a penetrating ulcer. As stated above, doppler flow should not be detected within an aortic intramural hematoma. Transesophageal echocardiography can help to distinguish between aortic intramural hematoma and penetrating aortic ulcer, as well as help to characterize the stability of the plaque. Also, transesophageal echocardiography can determine if the plaque has caused a rupture within the wall of the aorta, in which case extravasation of blood from the aorta would be identifiable.[29,38–40]

Infection tends to occur at regions where diseased tissue exists, such as atherosclerotic plaques. These plaques can form mycotic aneurysms, which may lead to rupture. In cases where endocarditis or other infectious processes are present, this should be a concern. Echocardiographic findings are not specific for the diagnosis of a mycotic aneurysm and must also be based on laboratory results and the clinical picture.[29,38–40]

Summary

Though sonography has certain limitations for thoracic imaging, it also has advantages over CT and MRI for certain diagnosis and treatment procedures, and its clinical utility may increase with future technical advances.

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Single-Photon Emission Tomography Imaging of the Chest

David H Lewis MD, Brian Kott MD, and Arnold F Jacobson MD PhD

Introduction
Pulmonary Thromboembolic Disease
Quantitative Lung Scintigraphy
Imaging of Receptors With Single-Photon Emission Tomography
Summary

We review single-photon emission computed tomography (SPECT) of the chest for practical applications that may be used by pulmonary disease specialists. First, we cover SPECT uses in pulmonary thromboembolic disease. Second, SPECT's applications in quantitative evaluation of the lung are reviewed, with special emphasis on lung volume reduction surgery. Finally, we consider the use of SPECT to characterize somatostatin receptors in lung masses. The role of SPECT will always be compared to the ever-advancing place of positron emission tomography chest imaging for patients with pulmonary disease. We believe that SPECT will continue to help pulmonary specialists take care of their patients in the years to come. *Key words: nuclear medicine, single-photon emission tomography, SPECT, perfusion, ventilation, pulmonary embolism, lung volume reduction surgery, tumors, somatostatin receptors.* [Respir Care 2001;46(9):940–945]

Introduction

Nuclear medicine techniques of imaging the chest have undergone a revolution in the last decade, as radiopharmaceuticals and imaging equipment have diversified and improved. The advent of clinical positron emission tomography (PET) as a tool to investigate cancer has been one of the most important developments. Nevertheless, single-photon emission computed tomography (SPECT) has also seen impressive improvements and changes. Herein we address imaging of pulmonary thromboembolic disease, pulmonary perfusion imaging in advance of lung volume reduction surgery (LVRS), and SPECT imaging of somatostatin receptors.

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Pulmonary Thromboembolic Disease

Planar ventilation/perfusion ($\dot{V}/\dot{Q}$) lung scanning using Xe-133 gas or technetium (Tc-99m) diethylenetriaminepentaacetic acid (DTPA) aerosol for ventilation images and Tc-99m macroagreggated albumin for perfusion images has been used for decades in the assessment of patients with suspected pulmonary thromboembolism. The image that shows intact ventilation with mismatched perfusion defects that are segmental and in at least 2 lung segments is the pathophysiologic hallmark of pulmonary thromboembolism and renders a diagnosis of high probability of pulmonary embolism. Although highly diagnostic and prognostic for a number of interpretive categories (especially for normal, high probability, and low probability with low pre-test probability), the test suffers inadequate sensitivity and specificity for pulmonary thromboembolism in the intermediate probability category and in the low probability category with a high pre-test probability from the clinical viewpoint.[1,2] Thus, attempts at reducing nondiagnostic studies are well worth investigating.

The advent of contrast helical CT angiography has brought into discussion the proper algorithm for evaluating patients suspected of having pulmonary thromboem-

bolism.[3] Well designed clinical outcome studies evaluating the use of spiral CT and lung SPECT for pulmonary thromboembolism are clearly needed, whereas there are already in the literature a number of articles in reference to the strong prognostic importance of various categories of V̇/Q̇ planar lung scan interpretation.[4–8]

SPECT of lung perfusion and ventilation requires tomographic acquisition of both ventilation performed with inhaled Tc-99m-labeled aerosols (such as Tc-99m DTPA) and perfusion performed with intravenous Tc-99m macroagreggated albumin. This study is ideally performed with a multi-detector gamma camera (2 or 3 detector heads), so that the scanning can be expeditiously performed with both comfort for the patient and accuracy in the rendering of image information.

Corbus et al reported on sequential ventilation and perfusion SPECT lung scanning in 985 consecutive subjects who had adequate follow-up at 3 months in 97% of the subjects.[9] Evidence or absence of pulmonary thromboembolism at 3 months was based on clinical characteristics, without performance of pulmonary angiography in 96% of patients. The breakdown of scan interpretations were as follows: high probability 14%, intermediate probability 4%, and low probability 82%. The reported sensitivity and specificity of lung SPECT based on clinical outcome were 83% (taking both high and intermediate categories as positive tests) and 92%, respectively. In contrast, the corresponding numbers from the Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED) study[1] were 82% and 52%. The authors concluded that lung SPECT provided diagnostic accuracy in 96% of patients and much better specificity than planar lung scans.

The reason that SPECT might provide more accurate results than planar V̇/Q̇ lung scans was suggested by Magnussen et al in an article describing a computerized model of pulmonary thromboembolism, which compared planar and SPECT imaging.[10] That work revealed that standard V̇/Q̇ planar lung scans failed to detect lesions in the lung bases, especially in the right medial basal segment, and also underestimated defect size, compared to SPECT. Those findings may be important, because lower lobe segments are the most reported sites of pulmonary thromboembolism.

An elegant approach to lung V̇/Q̇ SPECT is provided by true simultaneous (rather than sequential) SPECT acquisition of lung perfusion using Tc-99m macroagreggated albumin and ventilation using Kr-81m.[11] This technique is possible because the different photon energies of Tc-99m and Kr-81m can be resolved by the gamma camera SPECT system. A group of 7 patients with pulmonary vascular disease were studied and found to have a high semi-quantitative V̇/Q̇ ratio in lobar and segmental lung regions. This kind of quantitative information may be helpful to support visual interpretation of lung scans, but widespread use of this technique is limited by the high cost of Kr-81m as a ventilation agent.

Finally, in the setting of chronic pulmonary thromboembolic disease, lung perfusion SPECT was designated as the accepted standard for regional hypoperfusion in a small study of 5 patients with documented chronic pulmonary thromboembolism who also had CT scans.[12] CT showing a mosaic pattern of variable lung attenuation is a potential sign that chronic pulmonary thromboembolism may be the source of pulmonary hypertension. Compared with lung SPECT, CT had a sensitivity of 73% for regional hypoperfusion detection.

Quantitative Lung Scintigraphy

Scintigraphy has long been used as part of preoperative evaluation for possible lung resection. The quantitative lung scan, in which the region-of-interest analysis technique used in many nuclear medicine procedures is applied to standard lung perfusion and ventilation images, allows estimation of the contribution of a region of a lung to the total function, as might be determined from pulmonary function tests such as forced expiratory volume in the first second. Quantitation of regional lung perfusion is used most often to determine whether lung cancer patients will have sufficient postoperative pulmonary function to tolerate major procedures such as lobectomy or pneumonectomy.[13] Quantitation from planar perfusion and ventilation images is sufficiently accurate that even though lung perfusion SPECT, with its improved spatial resolution, is now readily available, there is little clinical need to employ this modality. Lung SPECT has become a valuable adjunctive procedure in the evaluation of patients under consideration for LVRS.

During the past decade, LVRS has become a viable treatment option for selected patients with severe emphysema. The primary objective of the procedure is the removal of poorly functioning hyperinflated lung tissue, which results in a better match between the sizes of the lungs and the chest cavity and improvement in the biomechanics of respiration and air flow dynamics.[14–16] Targets for resection in LVRS are regions with severe localized lung damage, reflected by substantial heterogeneity in imaging appearance of the lung parenchyma, most often at the lung apices or bases.[17] Though chest CT is universally used in assessing the severity of lung emphysema and in identifying potential targets for resection,[15,17,18] many surgeons also employ lung perfusion and ventilation scans as part of this process. Lung scans, both planar and SPECT, are used both qualitatively and semi-quantitatively, depending on the preference and expertise of the local practitioners.[15,17–20]

Lung perfusion scans are most often used as an adjunct to CT scans in assessing the distribution and degree of

emphysematous lung damage. Perfusion heterogeneity is typically judged visually, using a qualitative scoring system (eg, mild, moderate, severe), although region-of-interest analysis to provide more objective quantitation is possible. Though there is good correlation between CT and scintigraphic assessment of parenchymal involvement by emphysema, particularly in identifying apical and basal predominance, discordance between the anatomic and physiologic imaging methods does occur. In a study by Thurnheer et al of 70 LVRS patients, there was complete agreement in scoring (as either homogeneous, intermediately heterogeneous, or markedly heterogeneous) between CT and planar perfusion scans in only 35 of the patients (50%). Sixteen patients (23%) with homogeneous CT appearance were scored as heterogeneous on perfusion scans, including 9 considered markedly heterogeneous, providing further assistance to the surgeons in identifying target areas for resection.[18] McKenna et al used radionuclide lung perfusion scans to confirm the heterogeneous pattern of emphysema identified on CT, but did not indicate the frequency with which the patterns as judged by the 2 modalities were not in agreement.[15]

Perfusion SPECT provides improved anatomic detail for identification of regional parenchymal defects, and as such may allow identification of heterogeneity that is not appreciated on planar images. At present, the role of lung SPECT appears best defined as a visual adjunct for the surgeon, as SPECT has not been shown to be superior to planar imaging in characterizing the location and severity of perfusion heterogeneity. Using a semi-quantitative visual scoring system for defect severity in the upper and lower zones of each lung, Jamadar et al reported only a moderate correlation ($r = 0.52$) between planar and SPECT image scores, but nonetheless concluded that there appeared to be little benefit from the additional effort required to perform SPECT.[19] However, analogous to the comparison between plain radiographs of the chest and CT scans, there seems little doubt that SPECT perfusion images provide the surgeon a better guide for identifying local resection targets than do comparable planar views. Quantifying this expectation is nevertheless problematic, as it would require an objective means for correlating the preoperative surgical assessment of target areas with the portions of the lungs actually resected. Most published LVRS outcome analyses have provided only limited characterization of the surgical specimens, at most including their locations of origin (apex or base, left or right lung) and qualitative estimates of extent of resection.[19–21]

An additional benefit of the scintigraphic technique in assessing LVRS candidates is the potential for true quantitative analysis of the imaging studies, both before and after the surgical procedure. Several groups have examined quantitation of ventilatory function using Xe-133 gas, which provides information on both inflow and washout from the airways and is not subject to the deposition problems that limit the utility of Tc-99m aerosol preparations in patients with severe emphysema.[21–23]

Using planar imaging, Travaline et al found significant improvement in regional washout of radioxenon (a measure of small airway ventilatory mechanics) following LVRS, which correlated with increased forced expiratory volume in the first second.[21]

Suga et al, using dynamic Xe-133 SPECT, also documented improvement in regional ventilatory performance associated with increase in percentage forced expiratory volume in the first second following LVRS.[22] This group also reported quantitative improvement in regional perfusion after LVRS, measured by SPECT.[23,24]

In our clinic we have examined the potential utility of different quantitative measures of perfusion heterogeneity on lung SPECT. In a preliminary analysis of 14 patients who had perfusion SPECT before and after LVRS, changes in the whole-lung counts ratio ([maximum counts/pixel]/[mean counts/pixel]) showed the closest association with clinical outcome, with the 8 patients with the greatest decrease (reduced heterogeneity) having the best outcome (5 improved, 3 stable), whereas 3 of the 4 with the least change had adverse outcomes (2 deaths, 1 increased dyspnea).[25] Though the role of quantitation in lung scintigraphy for LVRS patients continues to evolve, it is possible that these methods will eventually be able to assist the surgeon not only in selecting the most appropriate candidates for the procedure, but also in identifying high-risk individuals in whom the potential benefits of surgery may not exceed the intraoperative and postoperative risk.

As noted above, planar and SPECT lung scan results have been used as parts of analyses of both the screening process for selecting LVRS candidates and the outcome among those who had the surgery. Observations such as the increased likelihood of surgery in patients with heterogeneous emphysema, particularly involving the apices, are hardly surprising, especially given that in many series the lung scan was part of the preoperative evaluation process.[15,19] Similarly, improved homogeneity of perfusion and ventilation being the expected outcome of successful LVRS, it is only the sometimes impressive appearance of uniformly perfused lung after LVRS in areas with minimal to absent perfusion before surgery (Fig. 1) that might be considered surprising.[23,24] What remains to be determined is how durable the improvement in ventilation and perfusion will be, given that, to date, most post-LVRS imaging evaluations have been performed at only 3–12 months after surgery.[19–24]

In conclusion, lung perfusion and ventilation scans, whether analyzed qualitatively, semi-quantitatively, or quantitatively, are an accepted element in the evaluation of patients under consideration for lung resection or LVRS. Though appreciation of SPECT imaging as a visual tool is

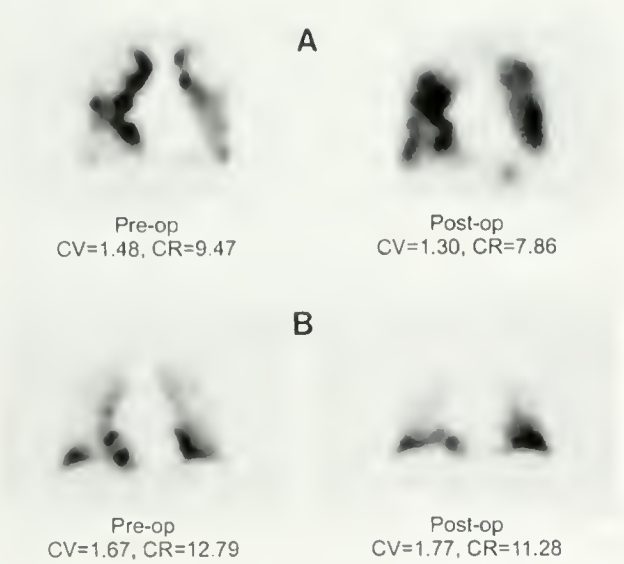

Fig. 1. Coronal images through the center of the lungs from before (pre-op) and after (post-op) lung volume reduction surgery (LVRS) perfusion single-photon emission computed tomography (SPECT) studies (left and right images, respectively) on 2 patients who were clinically improved after surgery. Both patients had bilateral upper lobe resections, but one post-LVRS study shows increased perfusion of the apices (panel A), whereas the other shows the most distinct improvement at the bases (panel B). Overall homogeneity is improved in both patients. The heterogeneity indices shown at the bottom of each image are the total lung coefficients of variation (CV = [pixel counts standard deviation]/[mean counts/pixel]) and counts ratio (CR = [maximum counts/pixel]/[mean counts/pixel]).

widespread, quantitative techniques employing SPECT data have yet to gain general acceptance. However, as more and better data associating SPECT analyses with clinical outcome results are published, this situation will probably change.

Imaging of Receptors With Single-Photon Emission Tomography

Scintigraphic imaging of somatostatin receptors in tumors has been a goal in cancer diagnosis and treatment since the early 1980s. Somatostatin receptors were first isolated and characterized in normal pituitary tissue in 1978.[25] Following this discovery, specific binding sites for somatostatin have been identified in vitro in a variety of normal human neuroendocrine tissues, including the respiratory tract. Not surprisingly, this led to the discovery of increased somatostatin receptor expression within various neoplasms. Specifically, in vitro over-expression of somatostatin receptors has been well documented in small cell lung cancers and carcinoids.[26,27] This phenomenon has been exploited and provided the foundation for scintigraphic imaging of these neoplasms, through the development of somatostatin receptor-targeted radiopharmaceuticals.

Since Bauer et al first synthesized an analogue of somatostatin, octreotide, the peptide has been labeled with In-111 (OctreoScan) and used to image somatostatin receptor-positive tumors in humans by conventional scintigraphy.[28–30] Octreotide scintigraphy of carcinoid and small cell lung cancer has been well documented as a highly sensitive modality for detection and evaluation of these tumors. Kwekkeboom et al found high sensitivity for evaluating carcinoid tumors, irrespective of tumor site or hormonal secretion.[31] Additionally, previously unsuspected localizations or sites not recognized with other imaging techniques were found in a majority of their patients. In regards to small cell lung cancer, octreotide SPECT scintigraphy has provided very accurate detection of primary lung tumors as well as distant metastatic disease, both suspected and unsuspected.[32] Curiously, and perhaps serendipitously, these and other studies observed similar highly sensitive visualization of all bronchogenic carcinomas (non-small cell and small cell lung cancer) as well as lung

Fig. 2. Coronal single-photon emission computed tomography (SPECT) image of the chest and upper abdomen from a technetium-99m depreotide scan in a 70-year-old man with a 6 cm heterogeneous low-density lung mass adjacent to the left pulmonary hilum. A curvilinear zone of increased uptake is seen in the medial left chest, with an adjacent photopenic center and another region of increased activity inferolaterally. These findings are consistent with a large malignant mass with a necrotic center. Normal physiologic distribution of activity in the abdominal organs (liver, spleen, kidneys) can also be seen. The diagnosis of squamous cell carcinoma was established at subsequent surgical resection.

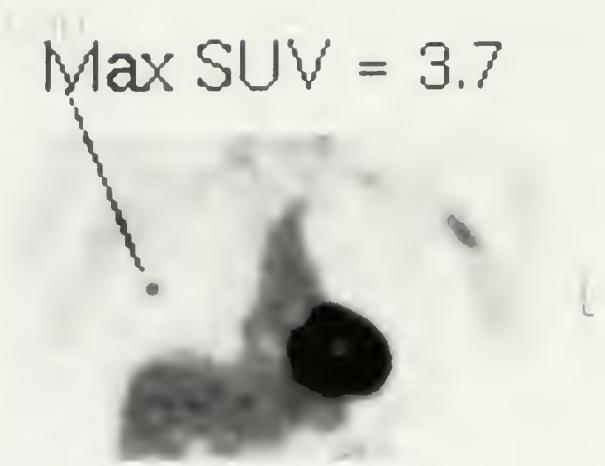

Fig. 3. A 40-year-old man with a remote history of resected right chest melanoma had a new right mid-lung nodule identified on routine chest radiograph. Chest computed tomography revealed a 12 mm round nodule with smooth margins, with no adenopathy or other parenchymal lung abnormalities. Coronal FDG-PET (2-[F-18] fluoro-2-deoxy-D-glucose-positron emission tomography) image of the chest shows moderately increased uptake in the peripheral right lung nodule, with a standard uptake value (SUV) of 3.7. At wedge resection, a focus of metastatic melanoma was found.

metastases from other tumors.[32–34] This was unexpected because in vitro somatostatin receptor expression in non-small cell lung cancer had not been shown and remains to be clarified. Despite in vitro differences in somatostatin receptor expression between non-small cell lung cancer and small cell lung cancer, recent clinical experience with somatostatin analog SPECT imaging in detecting non-small cell lung cancer has been encouraging.

Until recently, octreotide scintigraphy was limited to the labeled peptide In-111 pentetreotide (OctreoScan). The high cost of cyclotron production of the In-111 isotope, long half-life, and its relatively poor imaging characteristics had limited the clinical usefulness of octreotide SPECT scintigraphy in evaluating non-neuroendocrine tumors. A new Tc-labeled somatostatin analogue has been approved by the Food and Drug Administration as the radiopharmaceutical Tc-99m depreotide (NeoTect). High contrast resolution SPECT images with little normal pulmonary uptake, in conjunction with lower production costs, have allowed for recent expanded clinical applications of octreotide SPECT scintigraphy.

The evaluation of solitary pulmonary nodules with Tc-99m depreotide SPECT scintigraphy is a relatively recent application, with encouraging clinical results (Fig. 2). Blum et al found a 96.6% sensitivity of Tc-99m depreotide in solitary pulmonary nodules and an overall accuracy of 91% in delineating nodules as malignant or benign.[35–36] These results compared favorably with those reported for FDG-PET (2-[F-18] fluoro-2-deoxy-D-glucose positron emission tomography) in the evaluation of solitary pulmonary nodules.[36–39]

With the advantages of FDG-PET to screen not only for the lung nodule but also for regional and distant metastases[40] and its new and expanding other clinical applications (eg, colorectal cancer and melanoma) (Fig. 3), SPECT scintigraphy of the chest has taken somewhat of an academic "back seat" to this newly applied technology. However, this recent favorable comparison of SPECT to FDG-PET in the evaluation of solitary pulmonary nodules is important in regard to standard clinical practice. Specifically, SPECT scintigraphy is widely available and substantially less costly than dedicated PET systems. Comparable sensitivities and specificities to FDG-PET, combined with widespread availability and lower cost, may generate renewed interest and clinical application of somatostatin analog SPECT scintigraphy of the chest.

Summary

The wide availability of SPECT and the practical and easy use of Tc-99m radiopharmaceuticals make its use reasonable and efficient for symptom evaluation of disorders of the chest in which clinical concerns such as pulmonary embolism, quantitative lung function, or somatostatin receptor status of masses are raised.

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Letters

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Weaning Parameters: Who Cares!

Weaning parameters are a mainstay of managing the mechanically ventilated patient and are routinely measured in most intensive care units. The ratio of respiratory frequency to tidal volume (f/V_T), or rapid shallow breathing index, has become the most popular weaning parameter in the literature.[1,2] Most clinicians use the f/V_T ratio as an *extubation* parameter, ordering it when trying to determine if a patient is ready to be extubated. When a clinician orders a study or test, there should be a reasonable expectation that the results will help direct decision making for that patient. This same expectation should apply to the f/V_T ratio. The limited predictive ability of the f/V_T ratio argues that there is no role for its routine use in liberating patients from the ventilator.

The original study by Yang and Tobin showed a positive predictive value of 78% and negative predictive value of 95%.[3] However, subsequent trials have often shown much lower negative predictive values (8% to 100%).[1] In addition, many patients in these studies were never extubated, having met criteria for returning to mechanical ventilation before extubation. If one uses the f/V_T ratio as an extubation parameter, it is appropriate to focus on studies in which all study patients were extubated, thus providing a more reliable negative predictive value. Epstein reported that only 8 of 29 patients with an f/V_T ratio ≥ 100 measured off ventilatory support failed extubation, giving a negative predictive value of 28%.[4] Since patients tend to have lower f/V_T when measured on the ventilator,[1] this could be expected to improve the negative predictive value. However, Lee et al found that 12 of 13 patients (negative predictive value 8%) who had $f/V_T > 105$ on continuous positive airway pressure or pressure support were successfully extubated.[5]

One of the difficulties in applying the f/V_T ratio or other weaning parameters as predictive tools is deriving single cutoff values that can be applied to diverse patient populations. One study showed women to be 3 times more likely than men to have an f/V_T ratio ≥ 100.[4] Sixteen of 19 women with $f/V_T \geq 100$ were successfully extubated. Multiple clinical factors have been shown to impact a patient's f/V_T ratio and thus confound its application.

Most patients fail extubation for reasons (eg, aspiration, congestive heart failure, upper airway obstruction) that can't be predicted by routine respiratory values.[6] The majority of studies[1] have supported a positive predictive value $> 75\%$, and this is presumably as good as can be expected. More importantly, a false positive test means the patient is still given a trial of extubation. A false negative test means a patient potentially gets left on the ventilator when he or she might not need to be.

Let us assume that a patient has met your clinical criteria for extubation. How will ordering an f/V_T ratio affect your decision to extubate? If the ratio is low, the patient will presumably be extubated. What if the ratio is greater than 105? Will you leave the patient intubated, knowing there is a high probability the predictor is wrong and the patient is in fact ready for extubation? How many other predictive studies would you routinely order that are wrong more than half the time?

There have been no published prospective randomized trials examining the impact of weaning parameters on extubation success. Epstein[6] reported observational data that suggest that the use of weaning parameters doesn't change extubation outcome. During the study period, f/V_T ratio was ordered at the discretion of the medical intensive care unit team, and 94 patients were extubated after having f/V_T ratio measured within 8 hours of extubation. Eighty-one percent were successfully extubated. Ninety other patients were extubated without measurement of pre-extubation f/V_T ratio, and they had an almost identical 80% success rate.

It is important to remember that the original development of weaning parameters was driven by physicians' inability to clinically predict a patient's readiness for weaning. However, recent studies[7,8] have shown how to aggressively identify patients ready for extubation and shorten the duration of mechanical ventilation. The key is screening patients daily for their readiness to attempt a spontaneous breathing trial.

Though the screening criteria differed slightly between the studies, they both focused on 3 primary areas: adequate oxygenation, cardiovascular stability, and an acceptable mental status and cough. Patients who met these criteria were placed on a spontaneous breathing trial. If the patient passed the trial, the physician was notified. In 470 medical intensive care unit and cardiac care unit patients, the implementation of this respiratory therapist-driven protocol reduced the duration of weaning by 2 days, compared to patients weaned by their primary teams.[7,8] There was also a strong trend in both studies toward a lower incidence of tracheostomy in the protocol group.

Most critical care units are struggling with major personnel shortages, making it imperative that available staffing be used efficiently. Given the limited clinical utility of the f/V_T ratio and other weaning parameters, one cannot justify their routine use. Rather than having the respiratory therapists routinely measuring f/V_T ratios, they should be screening each ventilated patient daily for readiness to attempt a spontaneous breathing trial. Patients who pass this trial should be considered for extubation.

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Associate Editor Neil R MacIntyre responds:

I read with interest the letter written by Jack L DePriest addressing the f/V_T measurement (f/V_T ratio). I would offer the following comments.

First, the f/V_T ratio is simply an objective quantification of the ventilatory pattern. As such, an understanding of the circumstances under which it is measured is critical to interpreting its meaning. For example, a low f/V_T measured after 2 hours of a spontaneous breathing trial has quite a different meaning than a low f/V_T ratio measured while a patient is receiving 15 cm H_2O of pressure support. In the former case the patient may be ready for extubation; in the latter case the patient can only be said to be *tolerant* of the ventilatory support being given. The utility of the f/V_T ratio must thus be judged in the context in which it is measured.

Second, the McMaster University Evidence-Based Medicine Center recently performed a comprehensive evidence-based review of the ventilator weaning/withdrawal process.[1] This group concluded that the f/V_T ratio *in isolation* during a spontaneous breathing trial, though useful in large population studies to describe ventilator discontinuation likelihood, did not have sufficient predictive value to be of use in *individual* patients. Specifically, though they found that the f/V_T ratio during a spontaneous breathing trial was clearly higher in populations failing ventilator weaning/discontinuation, they could not find a specific cutoff number with enough accuracy to guide decisions in individual patients.

Third, agreeing that a cutoff value for the f/V_T ratio derived from population studies and used *in isolation* has limited value in individual patients does not mean agreeing that this measurement has no clinical utility. Indeed, the f/V_T ratio may have considerable value as part of a more comprehensive assessment of ventilator weaning/discontinuation potential. In 1999, the American College of Chest Physicians, the Society for Critical Care Medicine, and the American Association for Respiratory Care commissioned a task force to review the evidence on ventilator weaning/discontinuation (including the McMaster report[1]) and develop clinical practice guidelines.[2] This task force agreed with the McMaster group that the isolated f/V_T ratio has limited utility in the individual patient. However, the task force found considerable evidence to support therapist-driven ventilator discontinuation protocols using spontaneous breathing trials in patients who meet criteria for stable or resolving disease and who have evidence of adequate ventilatory drive. In these patients, the task force recommended that patient monitoring during the spontaneous breathing trial should include hemodynamics, hemoglobin oxygen saturation, subjective comfort, and *some assessment of the breathing pattern*. This last requirement is based on the observation by many that the respiratory pattern is one of the most sensitive indicators of the relationship between muscle loads and muscle capabilities. Specifically, rapid shallow breathing is often a very early sign of impending muscle overload and/or fatigue. In this context, the *change* in f/V_T during a 30–120 minute spontaneous breathing trial, rather than a set cutoff number, has been endorsed by the task force as the best way to quantify the ventilatory pattern response during a comprehensive spontaneous breathing trial assessment.

In conclusion, objectively quantifying the respiratory pattern is the most obvious benefit of the f/V_T ratio. Understanding the circumstances under which the f/V_T ratio is measured, however, is critical to proper interpretation. Recording increasing f/V_T ratios during spontaneous breathing trials is a convenient way to objectively document that patient intolerance (often from ventilatory muscle overload and/or fatigue) is developing. Conversely, stable f/V_T ratios (especially when < 105) imply patient tolerance of the spontaneous breathing trial and preservation of appropriate ventilatory muscle load/capabilities relationships. This measurement, however, should not be made in a vacuum. The respiratory pattern is but one "input" the skilled practitioner needs to assess when making decisions about ventilator weaning/discontinuation.

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Books, Films, Tapes, & Software

Chest Radiology Companion. Eric J Stern MD and Charles S White MD. Philadelphia: Lippincott Williams & Wilkins, 1999. Soft-cover, illustrated, 437 pages, $59.95.

These are exciting times in radiology. Technology has brought us computed tomography (CT), high-resolution CT, and spiral CT, along with magnetic resonance imaging, positron emission tomography scans, and a host of ways to examine the body and come ever closer to a specific diagnosis with diagnostic imaging techniques alone.

In this climate it is increasingly difficult to find a text that covers "the basics." Yet the chest radiograph is still the basic imaging tool for most of us involved in respiratory care. Of the additional chest imaging techniques, the CT scan is the other test that is most frequently required to understand the anatomy of disease. Chest CT particularly lends itself to clear delineation of the location and extent of disease in the lungs, pleura, and mediastinum.

The **Chest Radiology Companion** serves as a guide to the adult chest radiograph in disease states. Where appropriate, the chest film is accompanied by helpful CT images. This is not quite a basic book, in that it does not cover anatomy, but, on the other hand, it does serve as an introductory book of interpretation for many people who have had at least some experience with chest radiographs.

The intended audience is primarily radiology residents beginning their training, but the book would also be appropriate for medical students, respiratory therapists, pulmonary medicine trainees, and internal medicine residents, as well as emergency department providers and others who have reasons to look at chest radiographs.

The book includes a section on methods and chest CT protocols that will be of interest to anyone ordering those studies. There is a chapter on tube and line positions that will be helpful to those interested in critically ill patients. This is followed by sections on the lung, the mediastinum, the chest wall, pleura, and diaphragm, and common medical problems. The organization of the book is logical and fundamental. This is basically a book of interesting radiographs accompanied by key facts about the diseases shown. The key facts are presented in a bullet-point fashion, and a good deal of information is provided concisely. This information is accurate and as up to date as possible in a textbook these days. By no means is it intended to be all-inclusive, but it is sufficient for the purpose.

The references provided refer to the radiology literature and generally to classic articles. Only one reference is provided with each topic. One will need to look elsewhere to find further references regarding the illnesses and abnormalities covered in the key facts and radiographs.

There is abundant space remaining on many of the pages so that one could include his or her own notes regarding the various disease processes. An index is provided, referencing the subjects covered in the various chapters, and this would prove quite useful for those with a specific topic in mind.

This book fills a current need for simple texts that cover fundamental chest radiology. The accompanying CT images are most helpful. Many larger texts in radiology these days cover more specific areas and come at considerable expense. This book is fun to read, provides a lot of information in a compact form, and will prove to be most useful to a variety of health care practitioners, I should think.

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Imaging of Diffuse Lung Disease. David A Lynch MB, John D Newell Jr MD, and Jin Seong Lee MD. Hamilton, Ontario, Canada: BC Decker, 2000. Hard-cover (with CD-ROM), illustrated, 322 pages, $67.96.

As stated in the authors' preface, the underlying thesis of this book is that the imaging findings in patients with diffuse lung disease cannot be understood in isolation and must be integrated with the clinical presentation of the patient, along with the physiologic abnormalities and the pathology findings. For the most part the authors have accomplished their goal. Most of the chapters were jointly written by pulmonologists and radiologists, emphasizing the need for collaboration between these specialties to understand and manage patients with diffuse lung disease. The book is organized into 11 chapters for a total of 322 pages. There are 19 contributors, all but two of whom are from the same institution: the University of Colorado Health Sciences Center in Denver. The authors include academic subspecialty thoracic radiologists, pulmonary medicine physicians, and pathologists.

The introductory chapter reads very well and has excellent references. Chapter 2, on the pathology of diffuse lung disease, is but a brief overview. In that chapter, the authors avoid controversial issues of classification of some diffuse lung diseases such as is found with desquamative interstitial pneumonitis, respiratory bronchiolitis, and respiratory bronchiolitis-interstitial lung disease. In addition, the authors have used inconsistent nomenclature for the disease now called pulmonary Langerhans cell histiocytosis. The authors have used the older terms, eosinophilic granuloma and histiocytosis X, in other parts of the book. Admittedly picky, there are other minor inconsistencies in some of the material within the text, which with multiple authors is difficult to avoid. For example, bronchiectasis is defined as a *permanent* abnormal dilation of the airways in one chapter, whereas another chapter describes so-called "*reversible* bronchiectasis."

Chapter 3 is an excellent chapter in which the radiologic diagnosis of diffuse lung disease is discussed. One of the best features of this book is the inclusion of the authors' obvious formidable clinical experience; after the usual differential diagnosis is presented, the authors boil down the differential diagnosis to what we are likely to find in "actual clinical practice." However, readers of this book should be cautioned that their "actual clinical practice" will vary and may not be similar to that seen in the tertiary referral center in which the authors work.

Chapter 4 emphasizes the clinical history and presentation as well as the prognosis and outcome in patients with diffuse lung disease. This is probably the strongest chapter in the book. There is a very nice review of pulmonary function. The authors present conflicting literature and make insightful

summaries of the conflicting literature, even addressing subtle or minute areas of interest and argument in these areas of disagreement. The authors have the ability and wherewithal to tackle controversial subjects by asking and answering their own questions with a scholarly assessment of the literature, flavored subtly with their own experiences.

The chapter on pediatric diffuse lung disease is somewhat a rehash of many parts of the remainder of the book, but from an interesting pediatric perspective. The last chapter on quantification of diffuse lung disease is purely for the academic researcher only.

The authors make judicious use of tables. There is uniform image size in 2 columns. The image placement in the text sometimes leads to a little "hunting about" between the image and the image anchor in the text. The images presented are the "classic" presentations; emphasis is not placed on the spectrum of disease presentation. The image quality is somewhat inferior throughout the book, with many of the computed tomography scans appearing washed-out, at least in my copy. For example, neither air trapping nor ground glass opacity are seen very well in Figures 6–10 and 6–11, respectively. This may reflect on the publisher or printer more than on the authors.

A text to which this book can be rightly compared is *High Resolution CT of the Lung* by Drs Webb, Müller, and Naidich, the third edition of which was published by Lippincott Williams & Wilkins in the same year as this volume. Whereas Dr Webb's book emphasizes the high-resolution computed tomography appearance of disease and is more or less organized by high-resolution computed tomography pattern, this book is organized by disease. In other words, there is similar overall material in the 2 books, with different packaging of that material.

This book will be of greatest interest only to the most dedicated of sub-specialist in chest radiology and pulmonologists with strong interest in imaging.

Certainly this book is an excellent reference source for a scholarly distillation of the radiological/pathological/clinical literature of diffuse lung disease, as of the time of the writing of the book in 1999.

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Case Review: Thoracic Imaging. Phillip M Boiselle MD and Theresa C McLoud MD. (Case Review Series, David M Yousem MD, Series Editor.) St Louis: Mosby, 2001. Soft-cover, illustrated, 181 pages, $39.95.

The *Case Review Series* and *The Requisites* are 2 sets of radiology texts designed for radiology students, whether it be in a radiology residency or fellowship program, a corresponding surgical or medical subspecialty program, or a clinical practice where accurate radiography interpretations are routinely called for. Each set of texts is broken down into subspecialty areas, for example, in this instance, **Case Review: Thoracic Imaging** (the focus of this review) and *Thoracic Radiology: The Requisites* (previously reviewed in Respiratory Care).[1]

Thoracic Radiology: The Requisites is a textbook encompassing diseases of the chest and was written by Dr Theresa McLoud, a world-renowned chest radiologist at Massachusetts General Hospital, Harvard Medical School, and 4 distinguished associates, Dr Meenakshi Bhalla, Dr Jo-Anne O Shepard, Dr Beatrice Trotman-Dickenson, and Dr Phillip M Boiselle. **Case Review: Thoracic Imaging** is a constellation of 150 clinical, thoracic radiology test cases written by Dr Boiselle, Director of Thoracic Imaging at Beth Israel Deaconess Medical Center, Harvard Medical School, in conjunction with Dr McLoud.

Case Review: Thoracic Imaging is an extremely well written work. Whereas other publications of this type (case presentations and atlases) frequently leave the reader with a feeling of dissatisfaction because of the brevity of information conveyed or the fragmentation of the sentences used, **Case Review: Thoracic Imaging** is an enjoyable and satisfying read. One to three radiologic images are accompanied by 4 questions concerning normal or abnormal anatomy, radiologic findings or signs, differential diagnosis, pathogenesis, clinical correlates (signs/symptoms/results of other clinical tests), sensitivity and specificity of radiologic tests, staging, imaging protocols, the use of different imaging modalities, etc. Unavoidably, answers to early questions are often revealed in subsequent questions. This does not detract seriously from the value of the book, as the reader can cover up subsequent questions. There are usually 2 cases per page, with answers to the 4 questions, a single reference to the recent radiology literature, a cross-reference to *Thoracic Imaging: The Requisites*, and a short discussion of the radiologic findings and the disease entity on the following page. A space for notes is included at the end of each case but is frequently too small to be of any utility.

The book is divided into 3 sections, based on the level of difficulty of the case. The first section, "Opening Round," consists of 33 cases with questions appropriate for medical students or first and second year radiology residents. Topics covered include lung cancer, pneumothoraces, asbestos-associated pleural plaques, venous catheter positions, spine fracture, emphysema, miliary tuberculosis, chest wall masses, lobar collapse, pulmonary arterial hypertension, mediastinal hematoma, sarcoidosis, lung trauma, pneumomediastinum, pleural malignancy and effusions, esophageal malignancy, solitary pulmonary nodule, pneumonia, diffuse lung consolidation, bronchiectasis, mycetoma, cavitary masses, mediastinal masses, and lung segments using conventional chest radiographs and computed tomography (CT). Image quality is usually excellent. A few of the chest radiographs are dark (cases 1, 21, 22, 26, 28, 32, and 33). Coned images enhance the demonstration of subtle anatomy (case 20) or pathology. Only 1 typographic error was found in this section (case 27, condition misspelled "condtion").

The second section, "Fair Game," consists of 63 cases using nearly all the modalities of chest imaging: chest radiography, conventional and high-resolution CT, magnetic resonance imaging, and nuclear medicine ventilation-perfusion scans. The questions in this section are more sophisticated than in the first, and appropriate for third or fourth year radiology residents; fellows in chest radiology, pulmonary and critical care medicine and thoracic surgery; and practicing physicians and radiologists. Topics covered in the "Fair Game" section include mediastinal masses, silicosis, interstitial fibrosis, tuberculosis, interstitial pulmonary edema, bronchiectasis, arteriovenous malformation, aortic aneurysm, pulmonary infarction, acquired immunodeficiency syndrome (AIDS)-related lymphoma, lipoid pneumonia, lobar collapse, Wegener's granulomatosis, lymphangioleiomyomatosis, pneumonia in immunocompromised hosts, lymph node calcification, septic infarct, bronchopleural fistula, superior sulcus tumor, histiocytosis X, lymphangitic spread of tumor, lung cancer-nodal staging, mediastinal lipomatosis, azygos continuation of

the inferior vena cava, solitary pulmonary nodule, traumatic diaphragmatic rupture, sternoclavicular joint dislocation, tracheostomy tube complications, rounded atelectasis, sarcoidosis, carcinoid, Boerhaave syndrome, Kaposi sarcoma, bullae/emphysema, endobronchial metastases, chest wall lipoma, apical capping, bleomycin toxicity, superior vena cava syndrome, hypertrophic pulmonary osteoarthropathy, chest wall hematoma, enchondroma, pericardial effusion, bronchiectasis, achalasia, internal mammary lymphadenopathy, and transthoracic needle biopsy. The image quality in this section is excellent: in particular, many of the HRCT images show exquisite detail (cases 37, 52, 60, 61, 82, 92, 95). A few of the chest radiographs are suboptimal, hindering identification of the radiographic abnormality (cases 39, 40, 91). There were no typographic errors in this or the following section.

The third section, entitled "Challenge," includes 53 cases addressing unusual disease entities and requiring more advanced interpretive skills in high-resolution CT, the various pulse sequences of magnetic resonance imaging, and even conventional tomography (cases 99, 137, 144). A wide variety of topics are covered, including chronic eosinophilic pneumonia, right paratracheal air cyst/diverticulum, sternal dehiscence, mediastinitis, pulmonary gangrene, α-1-antitrypsin deficiency, Ritalin lung, bronchiolitis obliterans, metastasizing leiomyoma, asbestosis, post-pneumonectomy syndrome, Mounier-Kuhn syndrome, allergic bronchopulmonary aspergillosis, alveolar proteinosis, tracheomalacia, tracheal malignancies, mucoid impaction, fibrous tumor of the pleura, complications of heart, lung, renal and bone marrow transplantation, acute and chronic pulmonary embolism, endobronchial obstruction, metastatic thyroid carcinoma, Castleman disease, thrombosed saccular thoracic aortic aneurysm, relapsing polychondritis, Swyer-James-Macleod syndrome, *Mycobacterium avium-intracellulare* complex, congenital bronchial branching anomalies, aberrant right subclavian artery with dissection, sequestration, airway tuberculosis, AIDS, pulmonary edema in pregnancy, lipomatous hypertrophy of the interatrial septum, bronchiolitis obliterans organizing pneumonia, complications of tracheal stenting, thymic cyst, amiodarone toxicity, sarcoidosis, saphenous vein-graft pseudoaneurysm, small airways disease in AIDS and non-AIDS, pulmonary veno-occlusive disease, tracheal papillomatosis, idiopathic tracheal stenosis, echinococcal disease, mosaic pattern of lung attenuation, bronchial rupture, post-traumatic stricture, and chronic beryllosis. The images in this section are of excellent quality. Use of multiplanar images (cases 99, 112, 113, 119, 132, 135, 144, 145) nicely demonstrate normal and abnormal anatomy, particularly the cases of airway stenosis, where coronal or sagittal planes show the abnormality to better advantage than axial images. In case 135, (fractured airway stent), it should be pointed out that there are 2 types of stents: a metallic, self-expandable stent, which is easily inserted but difficult to remove (it becomes incorporated into the wall of the airway), and a silastic stent, which is more difficult to place but is easily adjusted or removed. Other than this one point, the comments are exceedingly accurate and the compromise between detail and brevity highly commendable.

The authors are successful in achieving their first goal, which is to review and illustrate a wide variety of thoracic diseases with which a graduating radiology resident should be familiar. Although the title "Thoracic Imaging" is used, there is a deficit in the coverage of cardiac diseases, which is not unique to this text. The authors are less successful in achieving their second goal, which is to "help the reader develop a sound framework with which to approach image interpretation in thoracic radiology." One could actualize this goal using a more orderly sequence of questions in the first section. A series of cases could be used to present and expand on interpretive concepts, such as the distinction of pleural versus parenchymal lung abnormalities, interstitial versus alveolar-filling patterns, and high-resolution CT of infiltrative lung disorders.

Case Review: Thoracic Imaging is an outstanding and affordable review of extracardiac, chest disease. I would highly recommend its use by all residents in diagnostic radiology, fellows in thoracic or pulmonary surgery, medicine, and radiology, and to any physician involved in the interpretation of radiologic images of the chest.

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Imaging of Diseases of the Chest, 3rd edition. Peter Armstrong, Alan G Wilson, Paul Dee, and David M Hansell. London: Mosby, 2000. Hard-cover, illustrated, 1039 pages, $199.

The second edition of **Imaging of Diseases of the Chest** published in 1995 is one of the most popular and widely read chest imaging text books. Like it predecessor, the present edition is suitable for radiology residents, radiology and pulmonary medicine fellows, and practicing radiologists, internists, and pulmonary medicine specialists. This text not only gives readers an imaging knowledge in chest disease but also has a good review of normal anatomy of the lung, pleura, and mediastinum, as well as physiology of the pleura, and a very good correlation with the clinical aspects of each disease as well. All of the 18 chapters in this textbook are divided into 3 main categories, including (1) technique of chest imaging, (2) anatomy of the chest, and (3) diseases of the chest.

The first main category leads off with a discussion of the technique of chest imaging, including conventional films as well as special techniques such as computed tomography (CT), high resolution computed tomography (HRCT), magnetic resonance imaging, and interventional radiology of the chest. However, there is no discussion of nuclear medicine. Typical protocols for CT scanning in some important diseases such as lung cancer staging, single pulmonary nodule, thoracic aorta, and large airways are presented. Clinical indications for CT scan of the chest are also provided. Because of the importance of HRCT in chest imaging, HRCT of the lung has been added as one of the chapters in this new edition. This new chapter includes the technique of HRCT, indications for HRCT, and protocols for diseases. Since HRCT is such a large topic, it is impossible to give all of the detail of HRCT in only one chapter. However, it does provide the readers with a good summary.

The diseases are divided according to the pattern of the lung abnormality, such as reticular pattern, nodular pattern, ground glass opacity and increased lung density, cystic air-space, distribution of disease, and airway disease. Interventional radiology of the

chest is discussed in the last chapter, including percutaneous needle biopsy, percutaneous drainage of intrathoracic fluid collection, bronchial angiography/embolization, tracheobronchial stents and superior vena cava stents. Indications, contraindications, techniques, and complications of each procedure are also pointed out.

The second main category provides a good basic knowledge of intrathoracic anatomy, as well as variations of normal anatomy. In Chapter 3, the authors discuss important findings and signs in chest imaging, for example, the "silhouette sign" and the "air bronchogram sign." All of these are demonstrated by exemplary cases, mostly with conventional radiographs.

The third main category is mainly focussed on diseases of the lung. They are divided into infection disease, neoplasm, pulmonary vascular disease, inhalation disease, drug and radiation-induced disease, immunologic disease, congenital disease, trauma, and miscellaneous lung diseases. Each of these categories receives a chapter, whereas other parts of the chest, such as the pleura, mediastinum, and airway, include all disease categories within only one chapter (for example, Chapter 14, "The Pleura and Pleural Disorders"). Because of the worldwide prevalence of acquired immunodeficiency syndrome, the authors separate this topic into its own chapter.

All chapters are concise, readable, and well-organized. Each chapter begins with a topic outline, which gives the readers a good scope before going into the detail of disease. Each disease category begins with an important clinical summary and follows with excellent radiographic examples, most of which are from conventional radiographs, but there are plenty of CT scan correlations as well.

The clinical aspects provided in this text are an important feature. For example, lung cancer can be more accurately staged if radiologists understand the tumor-node-metastasis classification, as noted in Chapter 7, "Neoplasms of the Lungs, Airways, and Pleura." The indices and references in this textbook are excellent.

This textbook is very large, and as such it is best used as a reference and is less suitably (though it is certainly not designed to be) used as a handbook. The images are excellently reproduced. Because this book is so easy to read, I highly recommend it to all radiology libraries, and to all physicians with special interest in imaging of the chest.

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Respiratory Care Equipment. 2nd edition. Richard D Branson RRT, Dean R Hess PhD RRT, and Robert L Chatburn RRT, Editors. Philadelphia: Lippincott Williams & Wilkins, 1999. Hard-cover, illustrated, 754 pages plus index, $59.95.

Respiratory care practice is a technology-related science that has witnessed the development and advancement of respiratory care equipment as the specialty has evolved. The practitioner who has been at patient bedsides for the past 25 or more years can attest to the dramatic changes in the equipment required for the clinician to practice in the accustomed manner. These rapid advances can pose an education challenge for clinicians aspiring to remain on top of their practice. My first reference book on respiratory care equipment, *Fundamental Respiratory Therapy Equipment* by Rau and Rau, was a valued addition to my respiratory library in the mid-1970s. However, as respiratory care knowledge has evolved, so have the books designed to educate the practitioner on respiratory equipment. The information, layout, and detail offered in contemporary respiratory equipment books are a marked improvement over the original texts. There are 2 contemporary respiratory equipment books on the market that address similar issues (eg, gas principles, medical gas generation and storage, gas delivery systems, artificial airways, manual resuscitators, bedside monitoring, blood gas measurement, ventilation [mechanical, transport, noninvasive, home, high-frequency]) to the second edition of **Respiratory Care Equipment**. *Principles and Applications of Cardiorespiratory Care Equipment*, edited by Eubanks and Bone, was released in 1994. The major topics addressed in Eubanks and Bone's book are comparable to chapters in the newer edition of Branson's book. The second book, also published in 1999, is the sixth edition of the book originally written by Steven P McPherson, *Mosby's Respiratory Care Equipment*, now edited by Cairo and Pilbeam. Chapters presented in that book are similar to Branson et al's book, with the exception that Cairo and Pilbeam's book devotes a chapter to sleep diagnostics. Additionally, **Respiratory Care Equipment** extends to include topics such as inhaled nitric oxide, extracorporeal life support, health information systems, and mechanisms to evaluate and monitor the multiple medical devices on the market.

Eighteen authors (including the editors, who wrote several of the chapters) contributed to this book of 28 chapters. The list of authors is a talented field; many are familiar to us by having previously published in RESPIRATORY CARE.

The book, which deals with somewhat dry technical information, is factually written and well referenced. The book has rare misspellings and editing errors (eg, Figures 7–2 and 7–3 are switched, and laryngoscope blades in Figure 7–20 are mislabeled), but overall the text represents a nicely prepared work. Several changes from the first edition of this book (1995) have been made. In addition to updating the medical devices appropriate to each topic, the chapters are lengthened to include a more detailed accounting of (a) cardiorespiratory monitoring, (b) noninvasive ventilation, (c) principles of extracorporeal life support, (d) medical device evaluation, and (e) nitric oxide inhalation. Within each chapter, troubleshooting boxes have been included to address problems commonly encountered with the various devices. A strong feature of the first edition, the inclusion of the American Association for Respiratory Care Clinical Practice Guidelines, has been updated and expanded in this second edition. The text is complemented with the addition of numerous tables, figures, and equation boxes. A glossary of commonly used respiratory terms is again included at the end of the book.

A nice addition to the second edition book is a study disk with 448 questions to test the reader on the material offered in the book. Each question provides feedback for the correct answer. The program works with Microsoft Windows 3.1 or Windows 95.

This book will make an excellent resource book for students of respiratory care whose goal is to assimilate the principles of contemporary equipment usage. Similarly, the second edition of **Respiratory Care Equipment** will serve as an easily accessible resource book for those respiratory therapy clinicians in need of updating their knowledge of various medical devices. This book deserves to be in the libraries of respiratory

therapy programs, departmental libraries, or in the home libraries of respiratory clinicians.

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Pharmacology for Health Professionals. Evelyn Salerno RPh PharmD. St Louis: Mosby. 1999. Soft-cover, illustrated, 827 pages plus appendixes, $45.

Respiratory therapists and nurses take for granted that medication administration is an integral part of their jobs. While the job of passing pills (or metered-dose inhalers) seems pretty routine, safe medication administration requires far more than simple reading ability. The wealth of knowledge one must possess to administer medications safely is tremendous and growing all the time. Clinicians need more than basic understanding of physiology, pathology, chemistry, and microbiology before they can fully appreciate the actions and interactions of specific drugs.

Keeping current in pharmacology has become more difficult each year, as new products are added to already lengthy lists of therapeutic agents. Not only does information on new products demand attention, but each year brings to light new data on established drugs. For authors of pharmacology books, the job of sifting through the mountains of available information, to separate the wheat from the chaff, has become increasingly challenging throughout the years.

Pharmacology for Health Professionals by Evelyn Salerno meets this challenge admirably. This well organized text offers a satisfactory compromise between huge chemistry-laden medical pharmacology texts and small drug handbooks that are too often light on details. Comprehensive in its scope, this book begins with clearly written sections on general principles of pharmaceutics and pharmacokinetics. Also well presented are chapters on substance abuse, lifespan considerations, and legal issues.

The remainder of the book's 18 general units is dedicated to specific therapeutic agents. Each unit focuses on physiologic systems or pathologic processes. System-focused units are introduced by brief but helpful reviews of normal physiology. Discussion of pathophysiology in each chapter is relatively sparse, but it is clearly written and more than adequate.

The author uses the "key drug" or *prototype* method for teaching students about large classes of drugs. From each general category of drugs, one or two specific "key drugs" are selected and examined in depth. Drugs selected as "key drugs" are representative ("prototypical") of all drugs within a category. Their modes of action, adverse effects, interactions, signs of overdose, and a variety of other clinical information are presented. Once students become familiar with a key drug, they are expected to extrapolate what they have learned to other drugs within the class. This approach is based on the usually valid assumption that within drug classes, major similarities among agents far outnumber their differences. Given an ever-expanding list of therapeutic agents, use of prototypes seems to be the only practical way to cover them.

Prototypes help students appreciate the shared characteristics of drugs, and they spare the reader from lengthy, redundant drug monographs common to most texts. However, they are unable to help one learn about the unique features of each drug. Specific precautions, exceptions to general rules, interactions, and adverse effects can differ greatly from one drug to another within each class. The author covers these exceptions and differences efficiently, as each major drug in every category receives its own brief exposition.

The book's primary emphasis is on clinical relevance. Offset information in boxes focuses on the practical, such as duration of action, peak serum levels, and treatment of overdose. Extensive discussions of biochemistry are less evident in this book than in many. This will perhaps increase its accessibility to its likely audience of students in 2-year nursing or respiratory care programs.

Pharmacology for Health Professionals is a well designed, easy-to-read book that covers a gigantic subject. Its 3 tables of contents make it quick to reference, although one would have been plenty. Some appendixes are useful and unique (eg, "Drugs that change urine or stool color" and "Time to draw blood for specific medications"), whereas others are perhaps less so (eg, "Sugar-free medications"). Illustrations are clear and well captioned; there are just enough of them to be helpful. At over 800 pages, the text tests the limits of paper-back binding. This trade-off translates into lower prices for students: at $45, Salerno's book offers excellent value, covering the same material as other pharmacology texts at a bargain price. And given the variety of competent pharmacology texts to choose from, cost can end up as the deciding factor in making course selections.

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AIDS Sourcebook, 2nd edition. Karen Bellenir, Editor. (Health Reference Series) Detroit: Omnigraphics. 1999. Hard-cover, illustrated, 752 pages, $78.

The second edition of the **AIDS Sourcebook** is an updated comprehensive compendium of information about human immunodeficiency virus (HIV) infection and AIDS (acquired immunodeficiency syndrome) written for HIV-infected individuals and their family members, caregivers of HIV-infected individuals, and the general public. This volume is a consummate survey, consisting of 6 sections: general information regarding the virus and transmission, epidemiology, HIV treatment guidelines (including prevention of opportunistic infections), HIV prevention strategies, status of clinical trials evaluating new therapies and vaccines, and, lastly, an extensive glossary of HIV-related terms, including listings of resources and organizations providing assistance to HIV-infected individuals. Developing a clear understanding of this disease can be challenging, given the complexity of HIV pathogenesis and the available treatments, as well as the rapid turnover of information in this field. The **AIDS Sourcebook** offers a full complement of information to the lay person from which to establish a foundation of knowledge about HIV and AIDS.

The **AIDS Sourcebook** is inclusive and well organized. Scientific data are presented clearly and succinctly and are substantiated with a limited number of references. Many chapters list suggested reading for further exploration of topics. Several chapters contain entire documents or excerpts of documents from a number of government agencies involved with HIV research, treatment, surveillance, and prevention. For example, the chapter devoted to antiretroviral therapies contains segments from "Guidelines for the Use of Antiretroviral Agents in HIV-Infected Adults and Adolescents." These guidelines include the principles of HIV treatment, which are intended for use by medical professionals in decision-making

for initiation of antiretrovirals in specific circumstances. This information is important, as it provides the sound basis for current interventions in HIV infection. Although often summarized for patients when treatment issues are addressed, these principles of therapy are rarely presented to patients in such degree of detail. Though these guidelines and frequent updates are available in their entirety through the HIV/AIDS Treatment Information Services Web site, the **AIDS Sourcebook** offers pertinent highlights within the context of additional information about antiretrovirals.

While much of this publication is devoted to medical management of HIV infection, there is also a substantial amount of valuable, practical information addressing matters such as eligibility for Social Security benefits and viaticals. These chapters provide straightforward descriptions and suggestions for information-gathering and decision-making for patients faced with the challenges of HIV disability. Resources for additional information are included. Other examples of very practical topics include home HIV testing, specific measures to reduce HIV exposure based on a person's particular risk profile, interventions to promote optimal nutrition in the individual experiencing HIV-related complications, recommendations for purchasing a water filter to eliminate possible infection with cryptosporidiosis, and considerations for participating in clinical trials, including ideas for pertinent questions an individual could pose to study personnel. The information gleaned from these chapters could only be obtained from a team of seasoned professionals, making this book a reference for down-to-earth aspects of living with HIV/AIDS.

The limitations of this text are fourfold. While the overall writing style of this text is clear and readable, the **AIDS Sourcebook** is primarily aimed at sophisticated, knowledgeable readers. As an example, the following is a description of viral load measurement: "changes in viral load are often reported in logarithmic or 'log changes.' This mathematical term denotes a change in the value of what is being measured by a factor of 10." Many patients don't have the background to find meaning in that definition. Individuals with HIV infection constitute a varied audience with diverse literacy levels. The extensive 88-page glossary, which is one of the highlights of this book, makes amends for this discrepancy with more straightforward definitions.

There is a general inconsistency in presentation of information in this book, since some of the chapters are derived from documents from a variety of agencies. The chapters written from a practical standpoint are presented in a more simple and direct format, with bulleted facts and recommendations. Meanwhile, chapters describing the immune system, HIV replication, surveillance data, and treatment are more challenging to read and probably require a college level reading capacity.

Another limitation relates to discussion of HIV diagnoses such as opportunistic infections. These chapters focus on aspects of prevention rather than treatment and are limited to *Mycobacterium avium* complex, *Pneumocystis carinii* pneumonia, fungal infections, cryptosporidiosis, toxoplasmosis, tuberculosis, cytomegalovirus, HIV wasting, and Kaposi sarcoma. One important absence is that of cervical dysplasia and invasive cervical cancer. These diagnoses, along with chronic vulvo-vaginal candidiasis and pelvic inflammatory disease, are the only HIV-related diagnoses specific to women. Two pages alone in a single chapter are devoted to the gynecologic issue of fluconazole administration to prevent yeast vaginitis. This volume repeats the often-encountered problem of not addressing concerns of women beyond perinatal transmission.

An important limitation is generic to any HIV-related publication. With the rapid emergence of new data, new treatments, and new guidelines, published information becomes obsolete almost immediately. The editor deals with this matter specifically by listing Web sites and other references for accessing the most current recommendations. One final concern regarding this volume is that despite the completeness and wealth of resources, the cost of $78 is likely to be prohibitive for many patients.

In summary, the **AIDS Sourcebook** is a comprehensive reference with utility for a knowledgeable lay person. Despite the aforementioned limitations, this book provides excellent descriptions of the HIV infection process, treatment of the disease, and prevention of transmission, as well as practical suggestions for the HIV-infected individual negotiating treatment, financial, psychological, and day-to-day practicalities.

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Quick Reference to Critical Care Nancy H Diepenbrock RN. Philadelphia: Lippincott Williams & Wilkins, 1999. Soft-cover, illustrated, 318 pages, $24.95

In the clinical arena, memory lapses related to minute details may be critical to patient care. It is with this premise in mind that Nancy Diepenbrock RN wrote **Quick Reference to Critical Care** for the critical care nurse. The purpose of the book, as alluded to in the title, is to offer "quick facts and quick solutions" when time is of the utmost importance—just enough information to jar the nurse's memory—leaving detailed information to more comprehensive textbooks.

Nurses, students, and residents "who can't remember everything" served as the impetus in the writing of this reference manual. This alleged "perfect bedside resource" is a 5×8-inch, 318-page book that is small enough to slip into a lab coat pocket. It is arranged in 11 chapters. Each chapter is organized alphabetically, with extensive intra-chapter cross-referencing. Each of the first 7 chapters corresponds to a body system: neurologic, cardiovascular, pulmonary, gastrointestinal/urinary, renal, endocrine, and hematologic/immune. Each chapter contains a variety of topics pertinent to the specified body system. Chapter 8, entitled "Drugs, Doses, and Tables," serves as a reference for drugs often administered in the intensive care setting. The bulk of the drugs listed in this section fall into the category of vasoactive substances and include a description of the drug, an infusion table, and a chart to summarize the cardiovascular effects of the drug. Chapter 9, entitled "Conversions, Calculations, Compatibility," contains useful information regarding height, weight, temperature, and dose-equivalent conversion charts. Two methods for calculating infusion rates and information on intravenous therapy round out this short chapter.

The focus of Chapter 10 is normal laboratory values. This chapter includes 3 referenced charts, with the remainder of the chapter (pages 282–289) containing unreferenced lab values. Finally, Chapter 11, "Miscellaneous," is a hodgepodge of useful reference information ranging from the Universal Precaution Guidelines of the Occupational Safety and Health Administration to the APACHE (acute physiology and chronic health evaluation) severity of disease classification. Some information contained within this chapter is redundant; for

example, signs, symptoms, and frequently used terms are all listed and defined in earlier chapters but reiterated in this section.

The major strength of this book is the many charts and figures, taken from approximately 10 sources. These charts and figures provide useful information and/or detailed medical illustrations; for example, the external ventricular drainage system diagram on Page 31 is well labeled and useful. Numerous mnemonics and a complete index also add to the value of this book.

The primary weakness of the manual is that the only referenced information is that contained in the figures and charts. The accuracy of all other information contained in the manual is dependent on the expertise of the author. Unfortunately, the manual contains many errors and inconsistencies in the information as printed. A sampling of some of the book's errors follows:

An incorrect formula for calculating the systemic vascular resistance (SVR) on Page 119: SVR = (MAP–CVP)/CO. Compare the correct formula (published in Morgan's *Clinical Anesthesiology*): SVR = (MAP–CVP × 80)/CO.[1]

On Page 125, digitalis is recommended for the treatment of WPW (Wolf-Parkinson-White) syndrome. Barash recommends that digitalis be avoided with the WPW syndrome patient since it increases conduction through the accessory bypass tract and decreases arteriovenous node conduction, consequently resulting in increased ventricular fibrillation potential.[2]

On Page 210, Addison disease is incorrectly related to hypofunction of the adrenal cortex of the kidney instead of the cortex of the adrenal gland.[1]

On Page 38 it is incorrectly stated that anticholinesterase is used to destroy antibodies, when in fact anticholinesterase drugs bind and inactivate the enzyme acetylcholinesterase.[1]

A sampling of some of the inconsistencies in the manual include:

When referring to Page 127 for information on acid-base balance, the nurse is directed to remember that "pH and HCO^{3-} in same direction = metabolic problem." On Page 128, the information on acid-base balance is in direct conflict with that on Page 127, and metabolic acidosis is listed as decreased pH, increased HCO^{3-}, and metabolic alkalosis is listed as increased pH, decreased HCO^{3-}.

The alveolar air equation on Page 126 assumes barometric pressure at sea level but uses 715 mm Hg in the equation. The author fails to mention that barometric pressure at sea level (760 mm Hg) minus water vapor pressure (47 mm Hg) at 37° C and 100% saturation are the values that should be provided in the formula so that the formula can be used at various altitudes.[2]

The oxygen content formula on Page 133 used 1.39 cc of oxygen per each 1 gm of hemoglobin, but on Page 150 uses 1.34 cc instead. Although both numbers are used in standard references, the author fails to standardize within the manual.

There is no consistent pattern as to the use of generic versus trades names for drug citations within the book. Some drug citations are listed in alphabetical order by the trade name while others are listed by the generic name.

Finally, the organization of the text, the font, and the print style are not conducive to easy reading. In addition, extensive cross-referencing within each chapter is very distracting.

In summary, the author has achieved the goal of providing a quick reference for the intensive care nurse. This book is written for the caregiver who desires only a "snapshot" of information regarding a given topic. The major limitation of the book is the volume of factual errors and inconsistencies in the information published. The material in the manual covers a wide range of topics, but in many respects lacks the extra details and accuracy to make it a valuable tool for clinicians.

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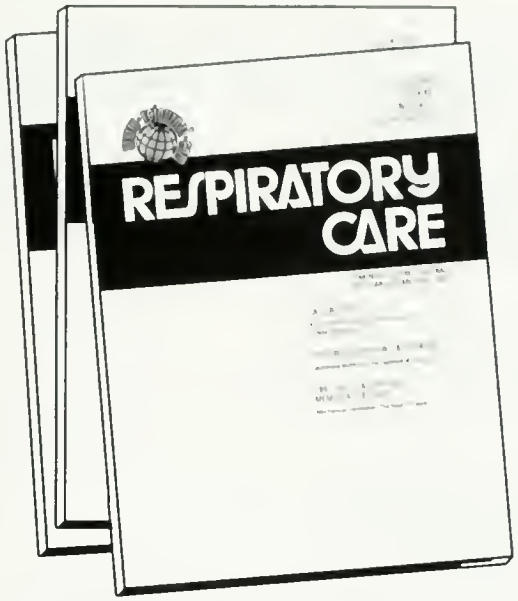

CRCE through the Journal—2001

CRCE through the Journal, a program for American Association for Respiratory Care (AARC) members to gain credit for continuing education, is now in its twelfth year. By reading RESPIRATORY CARE—the science journal for respiratory care professionals—and completing this examination, AARC members may earn credit for continuing education.*

This 50-item, multiple-choice examination is based on papers published from July 2000 through June 2001 in RESPIRATORY CARE. The issue and page numbers of the paper on which a question is based are shown in brackets following the question. You may consult the cited paper; however, we encourage you to read the paper in its entirety before answering the question. Choose the single most-correct answer, and mark the answer sheet, which is located following Page 976.

Mail your completed answer sheet by October 31, 2001. Answer sheets postmarked after October 31, 2001 will not be processed. The Answer Key for CRCE through the Journal will be published in the November issue of RESPIRATORY CARE. AARC members can access their CRCE transcripts via the AARC's Web site: http://www.aarc.org. Your CRCE through the Journal results will be available as soon as your answer sheet is scored and the score posted to your transcript.

We are indebted to Phillip D Hoberty EdD RRT, Assistant Professor and Director of Clinical Education, Respiratory Therapy Division, School of Allied Medical Professions, The Ohio State University, Columbus, Ohio, for coordinating and editing the examination and to his co-authors: F Herbert Douce MS RRT RPFT, Associate Professor and Director; Georgianna G Sergakis MS RRT, Graduate Teaching Assistant; and Sarah Varekojis MS RRT, Lecturer, Respiratory Therapy Division, School of Allied Medical Professions, The Ohio State University, Columbus, Ohio; Timothy B Opt'Holt EdD RRT, Associate Professor, Department of Cardiorespiratory Care, University of South Alabama, Mobile, Alabama; and Jerome F Walker EdD RRT, Professor, Cardiopulmonary Science Program, Lansing School of Nursing and Health Science, Bellarmine University, Louisville, Kentucky.

*The acceptance of these credits for the fulfillment of license-mandated continuing education is dictated solely by the licensure law of each individual state.

QUESTIONS:

Please follow the instructions on the previous page, and record your answers on the perforated form provided following Page 976.

1. The study conducted by Duarte et al demonstrated all of the following EXCEPT:

   a. a similar pattern of airway response in terms of magnitude and duration to albuterol administration via MDI and SVN
   b. total airway resistance returned to baseline after 90-120 minutes regardless of administration method
   c. no significant differences in the percent decrease in airway resistance among the 3 groups with respect to albuterol dose over time
   d. a significant decline in intrinsic PEEP following administration of albuterol regardless of dosage

   [July 2000;45(7):817-823]

2. The article by Witek lists all the following reasons for providing respiratory medications via the inhaled route of administration EXCEPT

   a. Utilizing higher doses than parental or oral preparations
   b. Optimizing the drug's therapeutic window
   c. Minimizing adverse and unwanted effects
   d. Delivering the drug directly to its site of action

   [July 2000;45(7):826-830]

3. Corkery describes 5 basic criteria a pulmonary drug delivery system must meet in order to effectively deliver macromolecules to the lung periphery, including:

   1. formulating the drug so that it is deliverable in a cloud containing particles of 1-3 μm with slow, deep inhalation
   2. reproducing the therapeutic drug dose from dose to dose
   3. accommodating flexible dosing
   4. being portable and easy to use

   a. 1 and 2 only
   b. 3 and 4 only
   c. 2, 3, and 4 only
   d. 1, 2, 3, and 4

   [July 2000;45(7):831-835)

4. O'Riordan describes all the following common uses of aerosolized antibiotics in cystic fibrosis patients EXCEPT:

   a. suppressive therapy
   b. eradication of Gram-negative organisms in early disease and prevention of colonization
   c. prevention of the development of resistance
   d. adjunct to intravenous therapy during acute exacerbations

   [July 2000;45(7):836-845]

5. Fink describes several improvements in aerosol administration due to design improvements, including:

   1. decreased oropharyngeal deposition
   2. decreased waste of drug
   3. greater ease of use
   4. improved lung deposition

   a. 1, 2, 3, and 4
   b. 2, 3 and 4 only
   c. 3 and 4 only
   d. 1 and 2 only

   [July 2000;45(7):874-885]

6. In a study by Stoller et al regarding the impact of a Respiratory Care Consult Service on house officers' knowledge of respiratory care ordering, the authors concluded that:

   a. Protocols implemented by therapists did not detract from house officers' expertise in respiratory care management.
   b. The use of protocols resulted in less accurate ordering of respiratory care management strategies.
   c. Protocols implemented by therapists resulted in less utilization of respiratory care management strategies by the house officers.
   d. House officers were unable to make recommendations for respiratory care management in hospitals where protocols are utilized.

   [August 2000;45(8):945-952]

7. In the article by Kuschner et al, the authors report that following benzocaine administration, methemoglobin levels approaching 30% in healthy individuals:

   a. should be considered lethal.
   b. will result in irreversible methemoglobinemia.
   c. may be tolerated producing few clinically important effects.
   d. are consistent with the manufacturer-recommended dose of benzocaine.

   [August 2000;45(8):953-956]

8. Beta-adrenergic bronchodilators are all derivatives of which naturally occurring neuromediator?

   a. epinephrine
   b. acetylcholine
   c. norepinephrine
   d. albuterol

   [August 2000;45(8):962-968]

9. According to recommendations from the Fifth Oxygen Consensus Conference, ambulatory LTOT equipment should weigh less than 10 pounds and provide at least the equivalent of:

   a. 8 L/min of continuous flow oxygen for 8 hours or more.
   b. 6 L/min of continuous flow oxygen for 2 hours or more.
   c. 2 L/min of continuous flow oxygen for 4 hours or more.
   d. 4 L/min of continuous flow oxygen for 2 hours or more.

   [August 2000;45(8):957-959]

10. According to Kallet, pulmonary artery occlusion pressure (PAOP) is an imprecise approximation of left ventricular end diastolic volume (LVEDV) under what circumstances?

    1. ARDS/ALI
    2. normal left ventricular compliance
    3. presence of mitral stenosis
    4. absence of pulmonary venous obstruction

    a. 1, 2, and 3 only
    b. 2, 3, and 4 only
    c. 1 and 3 only
    d. 2 and 4 only

    [September 2000;45(9):1072-1084]

11. According to Kallet, what factors are responsible for a decrease in patient work of breathing when using pressure controlled ventilation (PCV) relative to using volume controlled ventilation (VCV)?

    1. increased tidal volume
    2. high peak inspiratory flow
    3. longer inspiratory time
    4. demand-responsive changes in inspiratory flow

    a. 1 and 2 only
    b. 2 and 3 only
    c. 1 and 3 only
    d. 2 and 4 only

    [September 2000;45(9):1085-1096]

12. According to Kacmarek, which nitric oxide injection site into a high frequency oscillator ventilator results in acceptable NO concentrations?

    a. before the humidifier
    b. after the humidifier
    c. distal to the oscillator output
    d. any site is acceptable

    [September 2000;45(9):1097-1104]

13. What is the primary difference between pressure assist/control (P A/C) and pressure support ventilation (PSV), according to Williams, et al?

    a. P A/C is flow triggered but PSV is pressure triggered.
    b. P A/C is time cycled, but PSV is flow cycled.
    c. P A/C is pressure cycled, but PSV is time cycled.
    d. P A/C is volume limited, but PSV is pressure limited.

    [October 2000;45(10):1169-1181]

14. According to Johnson and Robart, what measures must be taken by the therapist to assure proper MDI technique?

    1. patient assessment
    2. use of a spacer
    3. patient instruction

    a. 1 only
    b. 1 and 3 only
    c. 2 and 3 only
    d. 1, 2, and 3

    [October 2000;45(10):1182-1187]

15. According to Fiore, which statement is true regarding the promotion of smoking cessation?

    a. Pharmacotherapy should be prescribed to patients unwilling to try to quit.
    b. There is a strong relationship between the intensity of smoking cessation counseling and its effectiveness.
    c. Brief dependence treatment is ineffective; all patients need long-term counseling.
    d. Some patients who use tobacco should not be encouraged to quit.

    [October 2000;45(10):1200-1260]

16. According to the U.S. Public Health Service Tobacco Use and Dependence Clinical Practice Guideline, what are the first line pharmacotherapies that reliably increase long-term smoking abstinence?

    1. Nortryptyline
    2. Bupropion SR
    3. Clonidine
    4. nicotine replacement

    a. 1 and 2 only
    b. 2 and 3 only
    c. 2 and 4 only
    d. 3 and 4 only

    [October 2000;45(10):1200-1262]

17. Which of the following is true regarding the assessment of dyspnea?

    a. Respiratory rate does not always correlate well with dyspnea.
    b. Forced expiratory volume is an accurate and objective predictor of dyspnea.
    c. The Borg scale is a useful dyspnea assessment tool in terminal care of the non-communicating COPD patient.
    d. Non-communicating patients can be determined dyspneic based on physical examination of breath sounds and accessory muscle usage.

    [November 2000;45(11):1331-1341]

18. Which statement(s) reflect potential mechanisms of dyspnea?

    1. an increased sense of respiratory effort expressed as the ratio of the pressure generated by the respiratory muscles to their maximum pressure generating capacity.
    2. a sense of breathlessness due to peripheral and central chemoreceptor response to hypercapnia and hypoxia.
    3. vagally-mediated dyspnea triggered by C-fibers located in the alveolar wall of the lung and its blood vessels

    a. 1 only
    b. 1, 2 and 3
    c. 2 only
    d. 2 and 3 only

    [November 2000;45(11):1342-1354]

19. When evaluating whether to initiate palliative noninvasive positive pressure ventilation (NPPV) in a terminally ill patient, which of the following questions should be answered affirmatively?

    a. Does the patient have symptoms (dyspnea, morning headaches, daytime hypersomnolence) that may respond to NPPV?
    b. Have patient wishes regarding invasive ventilation and CPR been discussed in advance and recorded?
    c. Does the patient know that NPPV is reversible and not linked to other treatment measures, and under his or her control at all times?
    d. Each response is correct.

    [November 2000;45(11):1376-1384]

20. There is evidence that suggests that each of the following adjustments to the mechanical ventilator may reduce dyspnea EXCEPT:

    a. increasing tidal volume in spontaneously breathing hypercapneic subjects.
    b. using a sine-wave flow pattern with volume control-continuous mechanical ventilation rather than a square wave or decelerating pattern.
    c. increasing mechanical assistance, for instance raising the level of pressure support of IMV rate to a level experienced as comfortable by the patient.
    d. adjusting inspiratory flow rate to a level not less than 70% or greater than 300% of the patient's spontaneously preferred level.

    [December 2000;45(12):1460-1467]

21. Recommended stress management techniques to deal with "compassion fatigue" and better allow caregivers to cope emotionally with dying patients include each of the following EXCEPT:

    a. providing for mental and physical distraction in the form of exercise or enjoyment of hobbies.
    b. practicing emotional detachment and stoicism by directing feelings inward.
    c. ensuring self-nurturance on a daily basis-getting adequate nutrition and sleep.
    d. spending time with family, friends and other sources of emotional support.

    [December 2000;45(12):1513-1522]

22. Which of the following has been established regarding dyspnea in the mechanically ventilated patient?

    a. Severity of post-traumatic stress disorder is reduced in survivors of respiratory failure when respiratory distress during mechanical ventilation is minimized.
    b. Mechanically ventilated patients are more comfortable when respiratory rate, tidal volume and inspiratory flow rate are under their own control.
    c. Dyspnea can be assessed in the communicating patient on a mechanical ventilator using visual analog or numerical intensity scales.
    d. Regular measurement of dyspnea may allow for reducing the amount of sedating drugs needed to maintain patient comfort and safety.

    [December 2000;45(12):1460-1467]

23. According to Health Care Financing Administration medical review policy guidelines, which of the following must be present to establish terminal stage pulmonary disease for purposes of hospice referral?

    a. unintentional progressive weight loss of > 10% body weight over the preceding 6 months
    b. right heart failure secondary to pulmonary disease (cor pulmonale)
    c. resting tachycardia: heart rate > 100/min
    d. $P_{O_2} < 55$ mm Hg or oxygen saturation ≤ 88% (on supplemental oxygen) or $P_{CO_2} > 50$ mm Hg)

    [December 2000;45(12):1478-1489]

24. In their preliminary observational study of transtracheal augmented ventilation (TTAV), Christopher et al demonstrated a significant improvement following a 3-month trial of nocturnal TTAV in which monitored parameter?

    a. P_{aCO_2}
    b. respiratory rate
    c. exercise capacity
    d. sleep efficiency

    [January 2001;46(1):15-25]

25. Following induction of apnea in the test subjects, Holt et al determined that there was not a significant increase in which parameters during Automode on the Servo 300A?

    1. Patient work of breathing
    2. Most negative deflection of pressure needed to generate a breath
    3. Duration of inspiratory effort
    4. Ventilator work of breathing

    a. 1 and 3 only
    b. 2 and 4 only
    c. 2, 3, and 4 only
    d. 1, 2, and 3 only

    [January 2001;46(1):26-36]

26. In the study conducted by Broach and Durbin, which parameter was affected when the authors demonstrated a significant increase in the rate of rise of core temperature in patients receiving a Thermax HCH?

    a. airway resistance
    b. average amount of chest tube drainage
    c. time to extubation
    d. quality or quantity of secretions

    [January 2001;46(1):37-42]

27. Which of the following statements most accurately reflects the findings of the study conducted by Turpeinen and Nikander?

    a. The deposition of terbutaline on the inspiratory filters was lower than the deposition of budesonide for both setups.
    b. The combination of breath-synchronized nebulization and the nebulizer connected directly to the ETT resulted in a higher inspiratory filter deposition for both drugs.
    c. The deposition of terbutaline on the waste filters was lower than the deposition of budesonide for both setups.
    d. In terms of drug delivery through an ETT, a solution of terbutaline is inferior to a suspension of budesonide.

    [January 2001;46(1):43-48]

28. In the case study described by Kallet et al, which of the following is NOT identified as a potential contribution to the development of bronchial obstruction?

    a. inadequate humidification
    b. inadequate suctioning
    c. lack of an appropriate lung inflation pattern
    d. application of intermittent PEEP

    [January 2001, 46(1):49-52]

29. All of the following are described by Hess and Gillette as techniques used to facilitate insufflation of gas into the central airway to improve carbon dioxide clearance EXCEPT:

    a. Intratracheal pulmonary ventilation
    b. Positive end-expiratory pressure (PEEP)
    c. Tracheal gas insufflation (TGI)
    d. High frequency jet ventilation

    [February 2001;46(2):119-129]

30. According to Nahum, which of the following is true regarding catheter tip location when performing tracheal gas insufflation (TGI)?

    a. Advancing the catheter closer to the carina enhances efficacy.
    b. The tip should be positioned exactly 6 cm above the carina.
    c. The catheter tip should be placed in the right mainstem.
    d. The least amount of turbulent airflow is desired for tip placement.

    [February 2001;46(2):149-157]

31. According to Blanch, which of the following parameter(s) should be monitored when using tracheal gas insufflation (TGI) in addition to conventional mechanical ventilation?

    a. static and dynamic lung compliance
    b. respiratory rate
    c. ETT position in airway
    d. delivered volumes and airway pressures

    [February 2001;46(2):158-166]

32. In order to prevent mucus plug formation when using tracheal gas insufflation, Delgado et al recommend which of the following?

    a. Instill 10 mL saline into catheter to flush.
    b. Remove and inspect the catheter every 8-12 hours.
    c. Occlude the expiratory limb of the circuit to check function.
    d. Provide supplemental mucolytic agents.

    [February 2001;46(2):185-192]

33. According to Bishop et al's study of the retention of intubation skills by RTs, what were the two most common errors in skill performance one year after initial training?

1. failure to assess for signs of difficult intubation
2. blade not moved so as to displace the tongue to the left
3. tube not inserted from the right side of the mouth
4. levering the blade on the upper teeth

a. 1 and 2 only
b. 2 and 3 only
c. 2 and 4 only
d. 3 and 4 only

[March 2001;46(3):234-237]

34. In Stoller, Orens, and Kester's study of the rate of RT turnover and the costs related to training new staff members at the 9 hospitals in the Cleveland Clinic Health System, what factor correlated with the turnover rate?

a. the cost of non-disposable equipment used
b. the ratio of hospital beds/ RT staff
c. the floor space of the RT department
d. the number of hand-held nebulizer treatments performed

[March 2001;46(3):238-242]

35. When Peruzzi et al studied patients with tracheostomy who were suspected of oropharyngeal dysphagia and possible aspiration, how did the colored dye method compare to videofluroscopy exam for detecting aspiration?

a. Both methods had equal numbers of false positives and false negatives.
b. The colored dye technique was more likely to detect aspiration.
c. The videofluroscopic technique detected a significantly greater frequency of aspiration.
d. A negative colored dye test effectively rules out the presence of aspiration.

[March 2001;46(3):243-247]

36. In Sottiaux's investigation of volume support ventilation (VSV) on the Siemens 300 ventilator, the author concluded that:

a. Patient-ventilator interaction does not affect tidal volume (V_T) stability in this mode of mechanical ventilation.
b. Only ineffective patient efforts during inspiration can account for fluctuations in V_T.
c. Only ineffective patient efforts during expiration can account for fluctuations in V_T.
d. Patient-ventilator interactions during both inspiration and expiration can affect the stability of the V_T.

[March 2001;46(3):255-262]

37. Which statement is a correct conclusion in MacIntyre's special article on innovations in mechanical ventilation?

a. Further innovations in mechanical ventilation are NOT needed.
b. The sole force (driver) that produces innovation is the desire for profit.
c. Innovators need funding sources to encourage both design development and assessment testing.
d. In assessing clinical benefit of an innovation, only the cost of the innovation needs to be considered.

[March 2001;46(3):267-272]

38. According to Kraut and Madias, the systematic approach to the analysis of acid-base disorders includes checking the accuracy of the parameters by applying what equation?

a. Bohr equation
b. Henderson equation
c. alveolar air equation
d. serum anion gap equation

[April 2001;46(4):392-403]

39. Arterial blood gas data for a 66-year-old man with COPD while at rest breathing 2 liters oxygen via nasal cannula are: pH 7.40, P_{aCO_2} 56 mm Hg, P_{aO_2} 72 mm Hg, H_{CO_3} 34 mEq/L. These blood gas data are consistent with what condition?

a. chronic respiratory acidosis with metabolic alkalosis
b. acute respiratory alkalosis with metabolic acidosis
c. chronic, uncompensated respiratory acidosis
d. fully compensated metabolic alkalosis

[April 2001;46(4):392-403]

40. What condition causes hypoventilation by decreasing the central neurological drive?

    a. amyotrophic lateral sclerosis
    b. obesity
    c. chest trauma
    d. cerebral edema

    [April 2001;46(4):366-383]

41. The P_{aCO_2} is 60 mm Hg and the hydrogen ion concentration is determined to be 60 mEq/L. According to the Henderson equation, what is the $H_{CO_3}^-$ in mEq/L?

    a. 24 mEq/L
    b. 36 mEq/L
    c. 48 mEq/L
    d. 60 mEq/L

    [April 2001;46(4):328-341]

42. In a lung model, what is the effect of removing the inner cannula from a tracheostomy tube?

    a. decrease work of breathing
    b. increase airway resistance
    c. decrease respiratory rate
    d. increase tidal volume

    [May 2001;46(5): 460-465]

43. When Freed et al studied patients with dysphagia caused by stroke, what was the effect of transcutaneous electrical stimulation of the neck?

    a. improved mental status
    b. improved swallowing function
    c. decreased ventilatory drive
    d. decreased mandibular pain

    [May 2001;46(5): 466-474]

44. Spratt and Petty identify what action of respiratory therapists in the home as fulfilling the appropriate role of "physician extenders?"

    a. ordering prescribed medications
    b. obtaining optimal reimbursement
    c. monitoring patient response to therapy
    d. diagnosing complementary conditions

    [May 2001;46(5): 475-488]

45. According to the revised AARC Clinical Practice Guideline for arterial blood gas analysis, what procedure should be performed a minimum of 3 times per year?

    a. replace all electrodes
    b. conduct proficiency testing
    c. perform 2-point calibration
    d. measure quality control materials

    [May 2001;45(5):498-505]

46. According to the updated AARC Clinical Practice Guidelines for pulmonary diagnostic procedures, what overall strategy is recommended for the assessment of quality and validation of results?

    a. CLIA regulations
    b. JCAHO laboratory guidelines
    c. AAP clinical assessment program
    d. NCCLS quality system model for health care

    [May 2001;45(5):506-513, 514-522, 523-530, 531-539]

47. In Shafazand, Canfield, and Kuschner's study of the 1-year quality-of-life (QOL) benefits of a new pulmonary rehabilitation program, which conclusion is correct?

    a. There were statistically significant improvements in all scales of the QOL tool.
    b. There was no improvement in either QOL or exercise tolerance.
    c. While exercise tolerance one year after the program improved, QOL was worse than before the program.
    d. A new multidisciplinary rehabilitation program is generally NOT effective in improving QOL of COPD patients.

    [June 2001;46(6):595-600]

48. According to Chatburn and Primiano's special article, what is the most important skill respiratory therapists possess?

    a. patient assessment
    b. airway management
    c. mechanical ventilation
    d. gas therapy

    [June 2001;46(6):604-621]

49. According to their article, why were Chatburn and Primiano proposing a new system for understanding modes of mechanical ventilation?

1. Operator manuals that come with current ventilators do a poor job of describing how modes operate.
2. Features that are identical on different ventilators are called by different names.
3. Features that operate differently on different ventilators are called the same thing.
4. There is a need to "decode" marketing jargon.

a. 1 and 2 only
b. 1 and 3 only
c. 1, 2, 3 and 4
d. 2, 3 and 4 only

[June 2001;46(6):604-621]

50. When employed in a mechanical lung model, which method of tracheal gas insufflation (TGI) did Delgado et al find to minimize the change in total-PEEP seen in other methods of TGI?

a. forward flow continuous TGI
b. forward flow expiratory TGI
c. bi-directional continuous TGI
d. reverse flow continuous TGI

[June 2001;46(6):577-585]

Make sure to double check your work and to mark the answer sheet clearly. Mail your completed answer sheet by October 31, 2001 to

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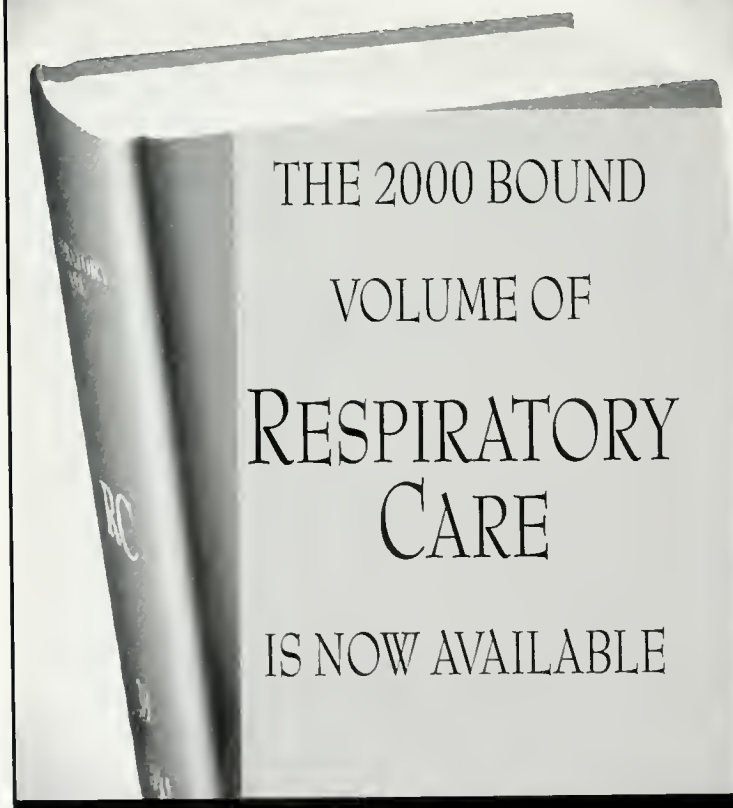

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MEDWATCH

THE FDA MEDICAL PRODUCTS REPORTING PROGRAM

For VOLUNTARY reporting by health professionals of adverse events and product problems

Page ___ of

Form Approved OMB No 0910-0291 Expires 4/30/96
See OMB statement on reverse

FDA Use Only (Hosp Care)

Triage unit sequence #

A. Patient Information

1 Patient identifier
In confidence

2 Age at time of event:
or
Date of birth:

3 Sex
☐ female
☐ male

4 Weight
___ lbs
or
___ kgs

B. Adverse event or product problem

1 ☐ Adverse event and/or ☐ Product problem (e.g., defects/malfunctions)

2 Outcomes attributed to adverse event (check all that apply)
☐ death (mo/day/yr)
☐ life-threatening
☐ hospitalization – initial or prolonged
☐ disability
☐ congenital anomaly
☐ required intervention to prevent permanent impairment/damage
☐ other

3 Date of event (mo/day/yr)

4 Date of this report (mo/day/yr)

5 Describe event or problem

6 Relevant tests/laboratory data, including dates

7 Other relevant history, including preexisting medical conditions (e.g., allergies, race, pregnancy, smoking and alcohol use, hepatic/renal dysfunction, etc.)

C. Suspect medication(s)

1 Name (give labeled strength & mfr/labeler if known)
#1
#2

2 Dose, frequency & route used
#1
#2

3 Therapy dates (if unknown, give duration)
(from/to or best estimate)
#1
#2

4 Diagnosis for use (indication)
#1
#2

5 Event abated after use stopped or dose reduced
#1 ☐ yes ☐ no ☐ doesn't apply
#2 ☐ yes ☐ no ☐ doesn't apply

6 Lot # (if known)
#1
#2

7 Exp. date (if known)
#1
#2

8 Event reappeared after reintroduction
#1 ☐ yes ☐ no ☐ doesn't apply
#2 ☐ yes ☐ no ☐ doesn't apply

9 NDC # (for product problems only)
– –

10 Concomitant medical products and therapy dates (exclude treatment of event)

D. Suspect medical device

1 Brand name

2 Type of device

3 Manufacturer name & address

4 Operator of device
☐ health professional
☐ lay user/patient
☐ other:

5 Expiration date (mo/day/yr)

6
model #
catalog #
serial #
lot #
other #

7 If implanted, give date (mo/day/yr)

8 If explanted, give date (mo/day/yr)

9 Device available for evaluation? (Do not send to FDA)
☐ yes ☐ no ☐ returned to manufacturer on ___ (mo/day/yr)

10 Concomitant medical products and therapy dates (exclude treatment of event)

E. Reporter (see confidentiality section on back)

1 Name & address

phone #

2 Health professional?
☐ yes ☐ no

3 Occupation

4 Also reported to
☐ manufacturer
☐ user facility
☐ distributor

5 If you do NOT want your identity disclosed to the manufacturer, place an " X " in this box. ☐

FDA

Mail to: MEDWATCH
5600 Fishers Lane
Rockville, MD 20852-9787

or FAX to:
1-800-FDA-0178

FDA Form 3500 1/96)

Submission of a report does not constitute an admission that medical personnel or the product caused or contributed to the event.

ADVICE ABOUT VOLUNTARY REPORTING

Report experiences with:

- medications (drugs or biologics)
- medical devices (including in-vitro diagnostics)
- special nutritional products (dietary supplements, medical foods, infant formulas)
- other products regulated by FDA

Report SERIOUS adverse events. An event is serious when the patient outcome is:

- death
- life-threatening (real risk of dying)
- hospitalization (initial or prolonged)
- disability (significant, persistent or permanent)
- congenital anomaly
- required intervention to prevent permanent impairment or damage

Report even if:

- you're not certain the product caused the event
- you don't have all the details

Report product problems – quality, performance or safety concerns such as:

- suspected contamination
- questionable stability
- defective components
- poor packaging or labeling
- therapeutic failures

How to report:

- just fill in the sections that apply to your report
- use section C for all products except medical devices
- attach additional blank pages if needed
- use a separate form for each patient
- report either to FDA or the manufacturer (or both)

Important numbers:

- 1-800-FDA-0178 to FAX report
- 1-800-FDA-7737 to report by modem
- 1-800-FDA-1088 to report by phone or for more information
- 1-800-822-7967 for a VAERS form for vaccines

If your report involves a serious adverse event with a device and it occurred in a facility outside a doctor's office, that facility may be legally required to report to FDA and/or the manufacturer. Please notify the person in that facility who would handle such reporting.

Confidentiality: The patient's identity is held in strict confidence by FDA and protected to the fullest extent of the law. The reporter's identity, including the identity of a self-reporter, may be shared with the manufacturer unless requested otherwise. However, FDA will not disclose the reporter's identity in response to a request from the public, pursuant to the Freedom of Information Act.

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FDA Form 3500-back

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The FDA Medical Products Reporting Program
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American Association for Respiratory Care

MEMBERSHIP APPLICATION

Please read the eligibility requirements for each of the classifications in the right-hand column, then complete the applicable section. All information requested below must be provided, except where indicated as optional. See other side for more information and fee schedule. Please sign and date application on reverse side and type or print clearly. Processing of application takes approximately 15 days.

- ☐ Active
- Associate
  - ☐ Foreign
  - ☐ Physician
  - ☐ Industrial
- ☐ Special
- Student

Last Name _____

First Name _____

Social Security No. _____

Home Address _____

City _____

State _____ Zip __ __ __ __ __ — __ __ __ __

Phone No. (_____) _____

Primary Job Responsibility (check one only)

- ☐ Technical Director
- ☐ Assistant Technical Director
- ☐ Pulmonary Function Specialist
- ☐ Instructor/Educator
- ☐ Supervisor
- ☐ Staff Therapist
- ☐ Staff Technician
- ☐ Rehabilitation/Home Care
- ☐ Medical Director
- ☐ Sales
- ☐ Student
- ☐ Other, specify _____

Type of Business

- ☐ Hospital
- ☐ Skilled Nursing Facility
- ☐ DME/HME
- ☐ Home Health Agency
- ☐ Educational Institution
- ☐ Manufacturer or supplier
- ☐ Other, specify _____

Date of Birth (optional) _____ Sex (optional) _____

U.S. Citizen? ____ Yes ____ No

Have you ever been a member of the AARC? _____

If so, when? From _____ to _____

Preferred mailing address: ☐ Home ☐ Business

For office use only

FOR ACTIVE MEMBER

An individual is eligible if he/she lives in the U.S. or its territories or was an Active Member prior to moving outside its borders or territories, and meets ONE of the following criteria: (1) is legally credentialed as a respiratory care professional if employed in a state that mandates such, OR (2) is a graduate of an accredited educational program in respiratory care, OR (3) holds a credential issued by the NBRC. An individual who is an AARC Active Member in good standing on December 8, 1994, will continue as such provided his/her membership remains in good standing.

PLEASE USE THE ADDRESS OF THE LOCATION WHERE YOU PERFORM YOUR JOB, NOT THE CORPORATE HEADQUARTERS IF IT IS LOCATED ELSEWHERE

Place of Employment _____

Address _____

City _____

State _____ Zip __ __ __ __ __ - __ __ __ __

Phone No. (_____) _____

Medical Director/Medical Sponsor _____

FOR ASSOCIATE OR SPECIAL MEMBER

Individuals who hold a position related to respiratory care but do not meet the requirements of Active Member shall be Associate Members. They have all the rights and benefits of the Association except to hold office, vote, or serve as chair of a standing committee. The following subclasses of Associate Membership are available: Foreign, Physician, and Industrial (individuals whose primary occupation is directly or indirectly devoted to the manufacture, sale, or distribution of respiratory care equipment or supplies). Special Members are those not working in a respiratory care-related field.

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Phone No. (_____) _____

FOR STUDENT MEMBER

Individuals will be classified as Student Members if they meet all the requirements for Associate Membership and are enrolled in an educational program in respiratory care accredited by, or in the process of seeking accreditation from, an AARC-recognized agency.

SPECIAL NOTICE — Student Members do not receive Continuing Respiratory Care Education (CRCE) transcripts. Upon completion of your respiratory care education, continuing education credits may be pursued upon your reclassification to Active or Associate Member.

School/RC Program _____

Address _____

City _____

State _____ Zip __ __ __ __ __ - __ __ __ __

Phone No. (_____) _____

Length of program

- ☐ 1 year
- ☐ 2 years
- ☐ 4 years
- ☐ Other, specify _____

Expected Date of Graduation *(REQUIRED INFORMATION)*

Month _____ Year _____

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Demographic Questions

We request that you answer these questions in order to help us design services and progroms to meet your needs.

Check the Highest Degree Earned

- ☐ High School
- ☐ RC Graduote Technicion
- ☐ Associote Degree
- ☐ Bachelor's Degree
- ☐ Master's Degree
- ☐ Doctorote Degree

Number of Years in Respiratory Care

- ☐ 0-2 years
- ☐ 3-5 yeors
- ☐ 6-10 yeors
- ☐ 11-15 Years
- ☐ 16 years or more

Job Status

- ☐ Full Time
- ☐ Part Time

Credentials

- ☐ RRT
- ☐ CRT
- ☐ Physicion
- ☐ CRNA
- ☐ RN
- ☐ LVN/LPN
- ☐ CPFT
- ☐ RPFT
- ☐ Perinotol/Pediotric

Salary

- ☐ Less than $10,000
- ☐ $10,001-$20,000
- ☐ $20,001-$30,000
- ☐ $30,001-$40,000
- ☐ $40,000 or more

PLEASE SIGN

I hereby apply for membership in the American Association for Respiratory Core ond have enclosed my dues. If opproved for membership in the AARC, I will obide by its bylaws and professional code of ethics. I outhorize investigation of all statements contained herein and understand thot misrepresentations or omissions of facts colled for is couse for rejection or expulsion.

A yearly subscription to RESPIRATORY CARE journal and *AARC Times* magozine includes an allocotion of $11.50 from my dues for each of these publicotions.

NOTE: Contributions or gifts to the AARC are not tax deductible os charitable contributions for income tax purposes. However, they may be tox deductible os ordinary ond necessary business expenses subject to restrictions imposed as o result of ossociotion lobbying activities. The AARC estimotes that the nondeductible portion of your dues — the portion which is allocoble to lobbying — is 26%.

Signature _____

Date _____

Membership Fees

Poyment must accompany your applicotion to the AARC. Fees are for 12 months. (NOTE: Renewal fees ore $75.00 Active, Associote-Industriol or Associote-Physician, or Speciol status; $90.00 for Associote-Foreign status; and $45.00 for Student stotus).

☐ Active	$ 87.50
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☐ Associote (Foreign)	$102.50
☐ Speciol	$ 87.50
☐ Student	$ 45.00
TOTAL	$_____

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Estoblished to recognize the specialty areos of respirotory core, these sections publish o bi-monthly newsletter that focuses on issues of specific concern to thot specialty. The sections olso design the specialty progromming ot the notionol AARC meetings.

☐ Adult Acute Care Section	$15.00
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Categories of Articles

Research Article: A report of an original investigation (a study). Must include: Title Page, Abstract, Key Words, Introduction, Methods, Results, Discussion, Conclusions, and References. May also include: Tables, Figures (if so, must include Figure Legends), Acknowledgments, and Appendixes.

Review: A comprehensive, critical review of the literature and state-of-the-art summary of a topic that has been the subject of at least 40 published research articles. Must include: Title Page, Outline, Abstract, Key Words, Introduction, Review of the Literature, Summary, and References. May also include: Tables, Figures (if so, must include Figure Legends), Acknowledgments, and Appendixes.

Overview: A critical review of a pertinent topic that has fewer than 40 published research articles. Same structure as Review Article.

Update: A report of subsequent developments in a topic that has been critically reviewed in RESPIRATORY CARE or elsewhere. Same structure as a Review Article.

Special Article: A pertinent paper not fitting one of the other categories. Consult with the Editor before writing or submitting such a paper.

Editorial: A paper addressing an issue in the practice or administration of respiratory care. It may present an opposing opinion, clarify a position, or bring a problem into focus.

Letter: A brief, signed communication responding to an item published in RESPIRATORY CARE or about other pertinent topics. Tables, Figures, and References may be included. The letter should be marked "For Publication."

Case Report: Report of an uncommon clinical case or a new or improved method of management or treatment. A case-managing physician must either be an author or furnish a letter approving the manuscript. Must include: Title Page, Abstract, Key Words, Introduction, Case Summary, Discussion, and References. May also include: Tables, Figures (if so, must include Figure Legends), and Acknowledgments.

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Test Your Radiologic Skill: A brief, instructive case report pertinent to respiratory care and involving imaging, including one or more radiographs or other images submitted as black and white glossy photographs that clearly illustrate the teaching points being made. Must include: Questions, Answers, and Discussion.

Preparing the Manuscript

Double-space the text and number the pages. Do *not* include author names, author institutional affiliations, or allusions to institutional affiliations anywhere except on the title page. On the Abstract page include the title but do not include author names. Begin each of the following on a new page: Title Page, Abstract, Text, Acknowledgments, References, each Table, each Figure, and each Appendix. Use standard English in the first person and active voice. Type all headings in initial-capital letters (eg, Introduction, Methods, Patients, Equipment, Statistical Analysis, Results, Discussion). Center the main section headings and place second-level headings on the left margin.

Abstract. Please ensure that the abstract does not contain any facts or conclusions that do not also appear in the body text. Limit the abstract to no more than 250 words.

Key Words. Include a list of 6 to 10 key words or key phrases in Research Articles, Reviews, Overviews, Special Articles, and Case Reports. Key words are best selected from the Medical Subject Headings (MeSH) used by MEDLINE and available at *http://www.nlm.nih.gov/mesh/Mbrowser.html*.

References. Assign reference numbers in the order that articles are cited in your manuscript. At the end of the manuscript, list the cited works in numerical order. Abbreviate journal names as in *Index Medicus*. List all authors. If the research has not yet been accepted for publication, cite the research as a personal communication (eg, Smith KR, personal communication, 2001); *however, you must obtain written permission from the author to cite his or her unpublished data.* Do not number such references; instead, make parenthetical reference in the body text of your manuscript. Example: "Recently, Jones et al found this treatment effective in 45 of 83 patients (Jones HI, personal communication, 2000)."

The following examples show RESPIRATORY CARE's style for references.

Paper accepted but not yet published:

Hess D. New therapies for asthma. Respir Care (year, in press).

Article in a journal carrying pagination throughout the volume:

Legere BM, Kavuru MS. Pulmonary function in obesity. Respir Care 2000;45(8):967-968.

Article in a publication that numbers each issue beginning with Page 1:

Kallstrom TJ. Focus on asthma—disease management: a role for the respiratory therapist. AARC Times 1999;23(Oct):16, 17, 19.

Corporate author journal article:

American Association for Respiratory Care. Clinical Practice Guideline. Removal of the endotracheal tube. Respir Care 1999;44(1):85-90.

Article in journal supplement: (Journals differ in numbering and identifying supplements. Supply information sufficient to allow retrieval.)

Barnes PJ. Endogenous inhibitory mechanisms in asthma. Am J Respir Crit Care Med 2000; 161(3 Pt 2):S176-S181.

Abstract in journal: (Abstracts citations are to be avoided, and those more than 3 years old should not be cited.)

Volsko TA, De Fiore J, Chatburn RL. Acapella vs flutter: performance comparison (abstract). Respir Care 2000;45(8):991.

Editorial in a journal:

Giordano SP. What's that sound? (editorial) Respir Care 2000;45(10):1167-1168.

Editorial with no author given:

The perils of paediatric research (editorial). Lancet 1999;353(9154):685.

Letter in journal:

Piper SD. Testing conditions for nebulizers (letter). Respir Care 2000;45(8):971.

Book: (For any book, specific pages should be cited whenever reference is made to specific statements or other content.)

Cairo JM, Pilbeam SP. Mosby's respiratory care equipment, 6th ed. St Louis: Mosby; 1999:76-85.

Corporate author book:

American Medical Association Department of Drugs. AMA drug evaluations, 3rd ed. Littleton CO: Publishing Sciences Group; 1977.

Chapter in book with editor(s):

Isono S. Upper airway muscle function during sleep. In: Loughlin GM, Carroll JL, Marcus CL, editors. Sleep and breathing in children: a developmental approach. (Lung Biology in Health and Disease, Vol 147, Claude Lenfant, Executive Editor.) New York/Basel: Marcel Dekker; 2000:261-291.

World Wide Web

American Lung Association. Trends in pneumonia, influenza, and acute respiratory conditions mortality and morbidity. February, 2000. http://www.lungusa.org/data. Accessed November 20, 2000.

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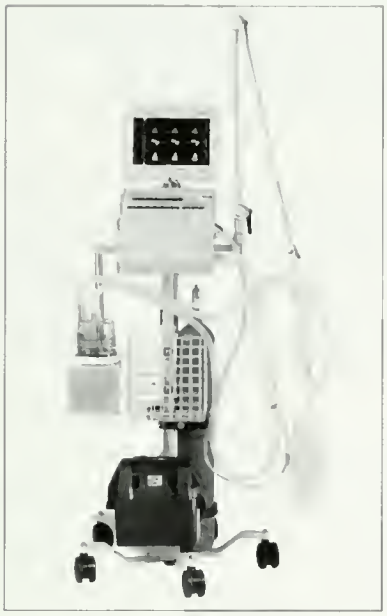
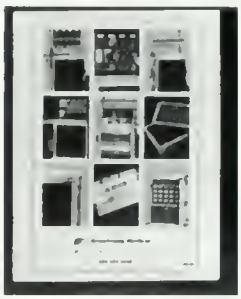


Graphics Monitor. Pulmonetic Systems introduces the LTM Graphics Monitor for its LTV series ventilators. According to Pulmonetic, the new monitor has a touch screen and shows controls, graphics, patient data, and messages on a color LCD display window. The company says monitor configurations can be customized using the Set Up feature and that other features include auto or manual scrolling, screen freeze, print functions, historical event log, patient information, date and time, and reference breaths and loops. For more information from Pulmonetic Systems, circle number 174 on the reader service card in this issue, or send your request electronically via "Advertisers Online" at http://www.aarc.org/buyers_guide/

Pocket Spirometer. Futuremed's SpiroBank is a pocket spirometer weighing 7oz. The manufacturer says it will perform full loop FVC, SVC and MVV tests, and make pre- and post-medication comparisons. According to Futuremed, the SpiroBank has an easy-to-read LCD display that shows results, including percentiles and interpretations. Full page reports can be generated by connecting SpiroBank directly to most printers, reports the company. Futuremed says that the SpiroBank uses a standard 9 volt battery and meets the latest spirometry standards. For more information from Futuremed America Inc, circle number 175 on the reader service card in this issue, or send your request electronically via "Advertisers Online" at http://www.aarc.org/buyers_guide/

CPAP Systems. Respironics introduces the REMstar Pro CPAP System with Integrated Humidification and Encore SmartCard. The company says that the REMstar Pro enables the user to cost-effectively monitor patient outcomes and improve compliance. The Encore SmartCard enables the REMstar Pro to easily record compliance and quality-of-life data with a simple mail-in card, according to the manufacturer's product literature. For more information from Respironics, circle number 176 on the reader service card in this issue, or send your request electronically via "Advertisers Online" at http://www.aarc.org/buyers_guide/



Cart Catalog. Armstrong Medical Industries introduces their 2001 Cart Catalog. The catalog features crash carts, pediatric emergency carts, anesthesia carts, medication carts, specialty carts, and utility carts, along with hundreds of accessories so that users can customize their carts to their exact needs, according to the company. For more information from Armstrong Medical Industries, circle number 177 on the reader service card in this issue, or send your request electronically via "Advertisers Online" at http://www.aarc.org/buyers_guide/

AARC's

47th

International RESPIRATORY CONGRESS

December 1-4, 2001
San Antonio, Texas

For 46 years the AARC's International Respiratory Congress has been the gold standard of respiratory care education and trade. For 46 years the AARC's International Respiratory Congress has delivered the highest quality programs with information that really matters. For 46 years the AARC has plowed its resources back into the profession, expanding the practice and influence of respiratory therapy in the health care system. Don't miss out on the largest and most comprehensive respiratory care meeting in the world, coming in 2001 to one of the most exciting cities in the US—San Antonio. For additional information, please call (972) 243-2272, or email clay@aarc.org.

Not-for-profit organizations are offered a free advertisement of up to eight lines to appear, on a space-available basis, in Calendar of Events in RESPIRATORY CARE. Ads for other meetings are priced at $5.50 per line and require an insertion order. Deadline is the 20th of the month two months preceding the month in which you wish the ad to run. Submit copy and insertion orders to Calendar of Events, RESPIRATORY CARE, 11030 Ables Lane, Dallas TX 75229-4593.

Calendar of Events

Date	AARC & State Society Programs	Contact
Sept. 10–12	Hawaii Society for Respiratory Care's 28th Annual State Respiratory Conference; **Waikiki Beach, HI**	Trace Ono at (808) 547-4241 or tracemaz@compuserve.com; www.rcphawaii.org
Sept. 11	Professor's Rounds 2001 Teleconference, Program 6	AARC, (972) 243-2272
Sept. 12–14	Alabama Society for Respiratory Care's Annual Meeting; **Birmingham, AL**	Bill Pruitt, (334) 434-3405, wpruitt@jaguar1.usouthal.edu
Sept. 13–14	28th Annual Seminar in Pulmonary Medicine and Sleep Disorders; **Pittsburgh, PA**	Pennsylvania Society for Respiratory Care; (412) 247-2603
Sept. 25	Professor's Rounds 2001 Live Videoconference, Program 7	AARC, (972) 243-2272
Sept. 26–27	MSRC Annual Meeting; **Sturbridge, MA**	Valeri-Ann Bolduc, (508) 429-7478, O2val@aol.com
Oct. 16	Professor's Rounds 2001 Teleconference, Program 7	AARC, (972) 243-2272
Oct. 23	Professor's Rounds 2001 Live Videoconference, Program 8	AARC, (972) 243-2272
Oct. 25–26	New Jersey Society for Respiratory Care's 2001 Shore Conference; **Atlantic City, NJ**	Maura McGovern at (973) 537-3919 or mmcgovern@saintclares.org; www.njsrc.org
Nov. 20	Professor's Rounds 2001 Teleconference, Program 8	AARC, (972) 243-2272
Dec. 1–4	47th International Respiratory Congress; **San Antonio, TX**	AARC, (972) 243-2272, www.aarc.org
Feb. 6–8, 2002	West Virginia Society for Respiratory Care's Winter Meeting; **Davis, WV**	Jay Wildt at (304) 442-7474 or jay.wildt@mghwv.org; or Anna Parkman at (304) 357-4837 or AParkman@ucwv.edu.

Date	Other Meetings	Contact
Oct. 9–11	Cardiorespiratory Diagnostics 2001; **Las Vegas, NV**	Medical Graphics Corporation, Mari Orke, (800) 950-5597, ext. 444, www.medgraph.com
Oct. 12	3rd Annual Rainbow Babies & Children's Pediatric/Neonatal Respiratory Conference; **Independence, OH**	Nancy Johnson at (216) 844-1954
Nov. 1–2	13th Annual Conference on High-Frequency Ventilation and Other Advances in Perinatal/ Neonatal Care; **Tempe, AZ**	St. Joseph's Hospital and Medical Center, Cathy Martinez, (602) 406-3512, fax (602) 406-4123
March 20–23, 2002	21st Annual Big Sky Pulmonary & Critical Care Medicine Conference; **Big Sky, MT**	American Lung Association of the Northern Rockies, (406) 442-6556, ala-nr@ala-nr.org

Notices

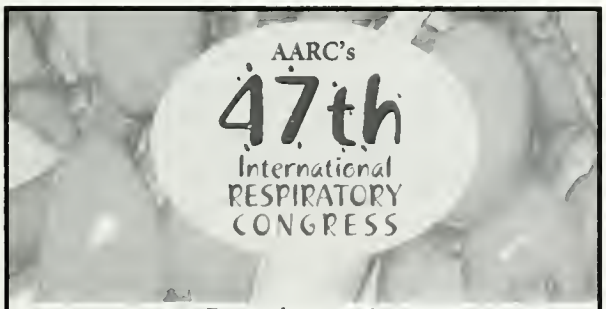
Notices of competitions, scholarships, fellowships, examination dates, new educational programs, and the like will be listed here free of charge. Items for the Notices section must reach the Journal 60 days before the desired month of publication (January 1 for the March issue, February 1 for the April issue, etc.). Include all pertinent information and mail notices to RESPIRATORY CARE Notices Dept, 11030 Ables Lane, Dallas TX 75229-4593

Scheduled Professor's Rounds 2001

Program #6 New Respiratory Drugs: What, When, and How—Joseph L Rau PhD RRT FAARC; Host Patrick J Dunne MEd RRT FAARC—Video August 14 Audio September 11

Program #7 Invasive Ventilation: The Latest Word—Richard H Kallet MS RRT; Host Richard D Branson BA RRT FAARC—Video September 25 Audio October 16

Program #8 Test Your Lungs-Know Your Numbers-Prevent Emphysema—Thomas L Petty MD FAARC; Host David J Pierson MD FAARC—Video October 23 Audio November 20



December 1-4, 2001
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American Association for Respiratory Care
http://www.aarc.org
- — Current job listings
- — American Respiratory Care Foundation fellowships, grants, & awards
- — Clinical Practice Guidelines

National Board for Respiratory Care
http://www.nbrc.org

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Asthma Management Model System
http://www.nhlbi.nih.gov

Keys to Professional Excellence
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Committee on Accreditation for Respiratory Care
http://www.coarc.com

The National Board for Respiratory Care—Examination Fees for 2001

Examination	Examination Fees
CRT	$190 (new applicant) $150 (reapplicant)
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CPFT	$200 (new applicant) $170 (reapplicant)
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For information about other services or fees, write to the National Board for Respiratory Care, 8310 Nieman Road, Lenexa KS 66214, or call (913) 599-4200, FAX (913) 541-0156, or e-mail: nbrc-info@nbrc.org

Authors in This Issue

Adams, Alexander . . . 891
Burns, David M . . . 902
Cantwell, G Patricia . . . 897
Chen, Xiao Juan . . . 891
Dawn, Samuel K . . . 912
DePriest, Jack L . . . 946
Dreyfuss, Didier . . . 888
Dubinsky, Theodore . . . 932
Gelman, Barry . . . 897
Gotway, Michael B . . . 912
Han, Jiang Na . . . 891
Hirnle, Robert W . . . 952
Jacobson, Arnold F . . . 940
Jacobson, Katherine L . . . 902
Johnson, F Wayne . . . 902
Kinninger, Katherine H . . . 902
Kott, Brian . . . 940
Krejci, Christopher S . . . 932
Kuluz, John W . . . 897
Lewis, David H . . . 940
Liu, Ya Ping . . . 891
Luo, Dong Mei . . . 891
Ma, Sui . . . 891
MacIntyre, Neil R . . . 947
Mahon, Thomas . . . 897
Marini, John J . . . 891
Marley, Rex A . . . 951
Martens, Sharon K . . . 952
McLaughlin, Gwenn E . . . 897
Mitsuoka, Masahiro . . . 902
Patterson, James R . . . 948
Ricard, Jean-Damien . . . 888
Schleien, Charles L . . . 897
Sell, Sandra . . . 953
Stern, Eric J . . . 911, 948
Sui, Si Hua . . . 891
Takasugi, Julie E . . . 949
Thomas, James . . . 897
Thoongsuwan, Nisa . . . 950
Trent, Erin J . . . 932
Webb, W Richard . . . 912
White, Charles S . . . 922
Zhu, Yuan Jue . . . 891

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RESPIRATORY CARE

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119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136
137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154
155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172
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- ✏ Mark only **one an**
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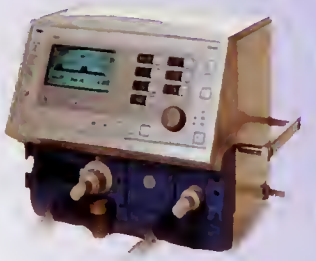

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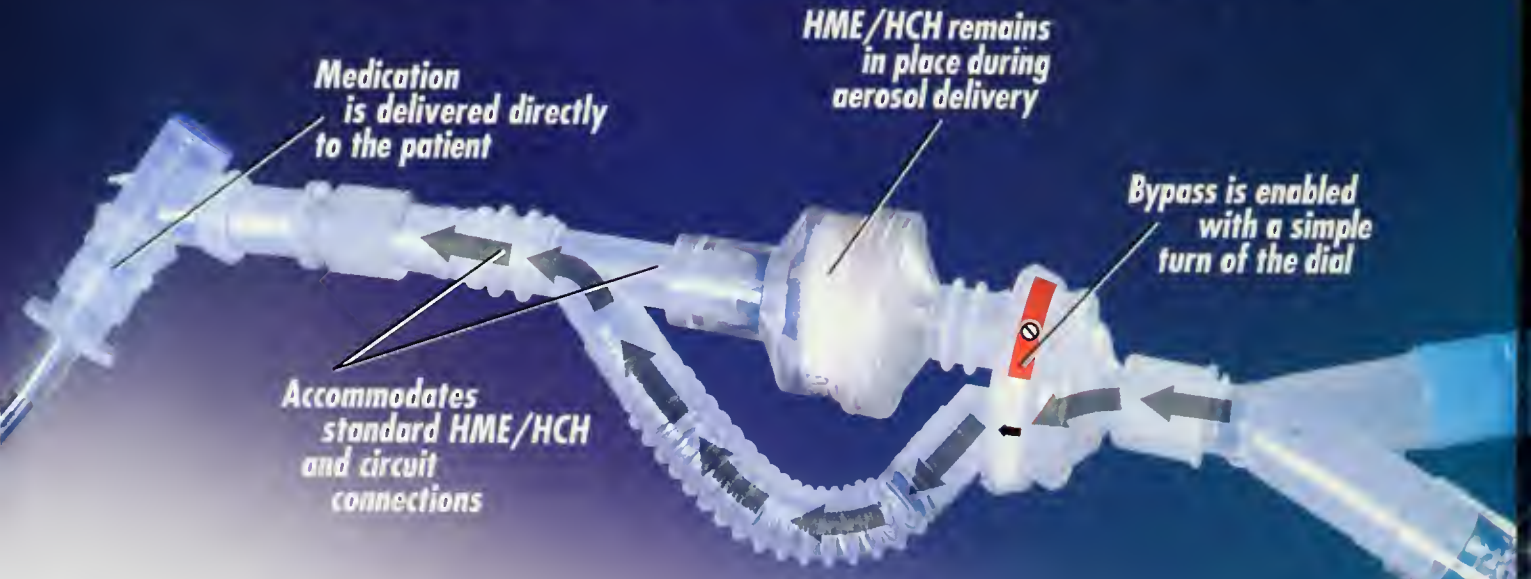
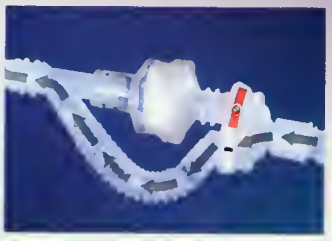
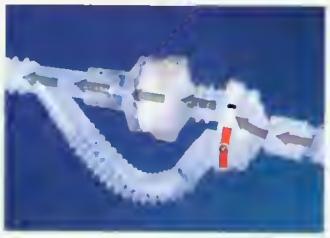
The aerosol delivery breakthrough with no breaks in the circuit


Medication is delivered directly to the patient
HME/HCH remains in place during aerosol delivery
Bypass is enabled with a simple turn of the dial
Accommodates standard HME/HCH and circuit connections



Bypass Position



HME/HCH Position

Until now, providing aerosolized medications to mechanically ventilated patients meant removing the HME/HCH – a procedure that can increase the risk of alveolar derecruitment, drying of airway secretions, and contamination to both patients and clinicians.

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CAUTION Federal (USA) law restricts this device to sale by or on the order of a physician

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